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Municipal Waste Combustion Assessment
Combustion Control at New Facilities

Energy and Environmental Research Corp., Durham, NC

Prepared for:

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REVIEW NOTICE AND DISCLAIMER

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ABSTRACT

The EPA's Office of Air Quality Planning and Standards (OAQPS) is developing emission standards and guidelines for new and existing municipal waste combustors (MWCs) under the authority of Sections 111(b) and 111(d) of the Clean Air Act (CAA). The EPA's Office of Research and Development (ORD) is providing support in developing the technical basis for good combustion practice (GCP), which is included as a regulatory alternative in the standards and guidelines. This report provides the supporting data and rationale used to establish baseline emission levels for model plants that represent portions of the planned and projected population of MWCs. The baseline emissions represent performance levels that are expected to be achieved by new plants in the MWC population that incorporate GCP. The baseline emissions, which were developed using the data base from the newest units in the existing population of MWCs, establish performance levels against which the effectiveness and costs of emission control alternatives can be evaluated.

FOREWORD

Based upon its analysis of Municipal Waste Combustors (MWCs), the Environmental Protection Agency (EPA) has determined that MWC emissions may reasonably be anticipated to contribute to the endangerment of public health and welfare and warrant further regulation. As a result, EPA's Office of Air Quality Planning and Standards is developing emission standards for new MWCs under Section 111(b) of the Clean Air Act (CAA) and guidelines for existing MWCs under Section 111(d) of the CAA.

In support of these regulatory development efforts, the Air and Energy Engineering Research Laboratory in EPA's Office of Research and Development has conducted an in-depth assessment of combustion control practices to minimize air emissions from MWCs. The results of this assessment are documented in the following reports:

Municipal Waste Combustion Assessment: Combustion Control at New Facilities, August 1989 (EPA-600/8-89-057)

Municipal Waste Combustion Assessment: Combustion Control at Existing Facilities, August 1989 (EPA-600/8-89-058)

Municipal Waste Combustion Assessment: Fossil Fuel Co-Firing, July 1989 (EPA-600/8-89-059)

Municipal Waste Combustion Assessment: Waste Co-Firing, July 1989 (EPA-600/8-89-060)

Municipal Waste Combustion Assessment: Fluidized Bed Combustion, July 1989 (EPA-600/8-89-061)

Municipal Waste Combustion Assessment: Medical Waste Combustion Practices at Municipal Waste Combustion Facilities, July 1989 (EPA-600/8-89-062)

Municipal Waste Combustion Assessment: Technical Basis for Good Combustion Practice, August 1989 (EPA-600/8-89-063)

Municipal Waste Combustion, Multi-Pollutant Study, Emission Test Report, Maine Energy Recovery Company, Refuse-Derived Fuel Facility, Biddeford, Maine, Volume I, Summary of Results, July 1989 (EPA-600/8-89-064a)

Municipal Waste Combustion, Multi-Pollutant Study, Emission Test Report, Mass Burn Refractory Incinerator, Montgomery County South, Ohio, Volume I, Summary of Results, August 1989 (EPA-600/8-89-065a)

The specific objective of this document, "Municipal Waste Combustion Assessment: Combustion Control at New Facilities," is to present the data and supporting rationale used to establish baseline emission estimates for a set of MWC model plants. Each model plant represents a class of MWCs which will be regulated by the Section 111(b) New Source Performance Standards (NSPS). The emission estimates provide a baseline against which emission reductions and costs of control alternatives were evaluated.

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1.0 SUMMARY

The EPA has completed an assessment of emission control performance and costs for add-on flue gas cleaning alternatives, and the results have been published in a technical support document as part of the 111(b) emission standards development effort for new municipal waste combustors (MWCs).[1] Twelve model plants were developed in the study to represent classes or groups of combustors in the new MWC population that will be subject to the standards. Baseline emission performance estimates were established for each of the model plants. A number of add-on control alternatives were applied to each model, and emission reduction and cost estimates were made for each control alternative. This report provides data and supporting rationale used to establish the baseline emission levels for each model plant. It was assumed in the study that all new MWCs would incorporate good combustion practice.

Table 1-1 presents design and operating data for the 12 111(b) model plants, including combustor type, unit size, and number of combustors per plant, and total plant size. Baseline emission levels were established for three air pollutants:

- polychlorinated dibenzo-p-dioxin and dibenzofuran (CDD/CDF)
- carbon monoxide (CO)
- particulate matter (PM)

Baseline emission levels are expressed as flue gas concentrations measured at the combustor or boiler outlet location, prior to treatment by add-on flue gas cleaning equipment. Unless otherwise noted, all emissions are normalized to 7 percent O_2. Table 1-2 summarizes the baseline emissions that were developed for each model plant. Baseline emissions for all pollutants were established using the available MWC emissions data base or, in cases where little or no data exist, engineering judgment.

The goals of this report are to present the data and supporting rationale used to establish the emission concentrations in Table 1-2. Section 2.0 provides background information describing the approach used to specify good combustion practice recommendations, and Section 3.0 provides the rationale used to establish the baseline emission estimates for each model plant.

TABLE 1-1. 111(B) MODEL PLANTS

COMBUSTOR TYPE	UNIT SIZE (tpd)	UNIT SIZE (Mg/day)	# OF COMB.	TOTAL PLANT CAPACITY (tpd)	TOTAL PLANT CAPACITY (Mg/day)	ANNUAL OPERATING HOURS*	ELECTRIC GENERATION‡	FUEL
Mass Burn Waterwall	100	91	2	200	182	5000	No	100% MSW
Mass Burn Waterwall	400	364	2	800	727	8000	Yes	100% MSW
Mass Burn Waterwall	750	682	3	2250	2045	8000	Yes	100% MSW
Mass Burn Refractory Split Flow (Volund)	250	227	2	500	455	8000	Yes	100% MSW
Mass Burn Rotary Waterwall (O'Connor)	350	318	3	1050	955	8000	Yes	100% MSW
Mass Burn Modular Excess Air	120	109	2	240	218	8000	Yes	100% MSW
Mass Burn Modular Starved Air	25	23	2	50	45	5000	No	100% MSW
Mass Burn Modular Starved Air	50	45	2	100	91	8000	Yes	100% MSW
RDF Spreader Stoker	500	454	4	2000	1818	8000	Yes	100% RDF
RDF Spreader Stoker	500	454	4	2000	1818	8000	Yes	50% RDF 50% Wood
RDF Bubbling Fluidized Bed (FBC)	450	409	2	900	818	8000	Yes	100% RDF
RDF Circulating Fluidized Bed	450	409	2	500	454	8000	Yes	100% RDF

*24 hr/day x 333 days/yr = 8000 hr/yr
100 hr/wk x 50 wk/yr = 5000 hr/yr
‡All model plants produce steam.

TABLE 1-2. 111(B) BASELINE UNCONTROLLED EMISSIONS

COMBUSTOR TYPE	UNIT SIZE (tpd)	(Mg/day)	# UNITS	CDD/CDF (ng/dscm)	CO (ppmv, 4-hr avg)	PM (mg/dscm)
Mass Burn Waterwall	100	91	2	200	50	4600 (2 gr/dscf)
Mass Burn Waterwall	400	364	2	200	50	4600
Mass Burn Waterwall	750	682	3	200	50	4600
Mass Burn Refractory Split Flow (Volund)	250	227	2	300	100	4600
Mass Burn Rotary Waterwall (O'Connor)	350	318	3	300	100	4600
Mass Burn Modular Excess Air	120	109	2	200	50	4600
Mass Burn Modular Starved Air	25	23	2	300	50	230 (0.1 gr/dscf)
Mass Burn Modular Starved Air	50	45	2	300	50	230
RDF Spreader Stoker	500	454	4	1000	100	9200 (4 gr/dscf)
RDF Bubbling Fluidized Bed (FBC)	450	409	2	20	50	9200
RDF Circulating Fluidized Bed	450	409	2	400	50	9200

2.0 BACKGROUND

On July 7, 1987, EPA published an Advance Notice of Proposed Rulemaking (ANPR) which announced EPA's intent to develop new source performance standards (NSPS) for new MWCs, and emission guidelines for existing MWCs under the authority of Section 111 of the Clean Air Act.[2] In conjunction with the ANPR, EPA issued operational guidance for new mass burn waterwall, modular starved air, and refuse-derived-fuel fired MWCs. The operational guidance was intended to serve as an interim tool to be used in Best Available Control Technology (BACT) determinations for siting new MWCs under the Prevention of Significant Deterioration (PSD) provisions of the Clean Air Act. The guidance specified that combustion controls are a necessary part of BACT for new MWCs.

The background information that led to the MWC regulatory decision was compiled and published in a Report to Congress.[3] As part of this effort, preliminary recommendations were made defining good combustion practices for new mass burn waterwall, modular starved air, and RDF fired MWCs.[4] Good combustion practices are expected to minimize emission of organics from MWC systems. The original recommendations included three elements:

- Design
- Operation/Control
- Verification

The requirements to satisfy these elements are:

- MWCs must be designed in a manner that minimizes air emissions.
- MWCs must be operated within an envelope dictated by the design of the combustion system, and controls must be in place to prevent operation outside of the established operating envelope.
- The performance of the combustion system must be verified by way of compliance testing and through continuous monitoring of key design and operating parameters, such as combustion air flows, gas temperatures, CO flue gas concentrations, and O_2 flue gas concentrations.

The revised recommendations for good combustion practices used in this report are presented in Table 2-1. The revised recommendations are similar to those provided in the Report to Congress with the exception of changes in some of the CO emission limits and the addition of a recommendation on PM control device operating temperature to address low temperature formation of CDD/CDF.

The good combustion practices defined in this report are designed to: (1) maximize in-furnace destruction of organic compounds, and (2) minimize conditions that lead to low temperature formation of CDD/CDF. Conditions within the combustion process that satisfy the first goal includes:

- Mixing of fuel and air to minimize the existence of long-lived, fuel-rich pockets of combustion products.

- Attainment of sufficiently high temperatures in the presence of oxygen for the destruction of hydrocarbon species.

- Prevention of quench zones or low temperature pathways that will allow partially reacted fuel (solid or gaseous) to exit the combustion chamber.

All of these conditions are interrelated; successful destruction of trace organic species requires that all three conditions be satisfied in the MWC system. Mixing is not sufficient unless it is achieved at temperatures that ensure thermal destruction of organic compounds. Completion of the mixing process at adequate destruction temperatures prevents escape of combustibles through low temperature pathways. Despite the continuing advancements made in combustion control, perfect mixing will never be achieved in a combustion system, whether conventional or waste fired. As a result, zero organic emissions will not occur. The goal of good combustion practice is to provide the conditions that will minimize air emissions of concern.

One important component which was not explicitly included in the original recommendations addresses the potential for low temperature formation of CDD/CDF. These formation phenomena have been measured at several full scale MWCs, including those at Prince Edward Island; Pittsfield, MA; North Andover, MA; and Pinellas County, FL.[5,6,7,8]

TABLE 2-1. GOOD COMBUSTION PRACTICES FOR MINIMIZING TRACE ORGANIC EMISSIONS FROM MUNICIPAL WASTE COMBUSTORS

DESIGN	
Temperature at fully mixed height	1800°F (982°C)
Underfire air control	At least 4 separately adjustable plenums. One each under the drying and burnout zones and at least two separately adjustable plenums under the burning zone (MB/WW). As required to provide uniform bed burning stoichiometry (RDF)
Overfire air capacity (not an operating requirement)	40% of total air (MB/WW, RDF) 80% of total air (MOD/SA)
Overfire air injector design	That required for penetration and coverage of furnace cross-section
Auxiliary fuel capacity	That required to meet start-up temperature and 1800°F (982°C) criteria under part-load conditions
Downstream flue gas temperature	<450°F (<232°C) at PM control device inlet
OPERATION/CONTROL	
Excess air	6-12% oxygen in flue gas (dry basis) (MB/WW and MOD/SA). 3-9% oxygen in flue gas (dry basis) (RDF)
Turndown restrictions	80-110% of design - lower limit may be extended with verification tests
Start-up procedures	On auxiliary fuel to design temperature
Use of auxiliary fuel	On prolonged high CO or low furnace temperature
VERIFICATION	
Oxygen in flue gas	Monitor
CO in flue gas	Monitor - 50 ppm on 4 hour average, corrected to 7% O2 (MB/WW and MOD/SA). 100 ppm at 7% O2 (RDF)
Furnace temperature	Monitor - minimum of 1800°F (982°C) (mean) at fully mixed height across furnace
Adequate air distribution	Verification Tests
Downstream flue gas temperature	Monitor - <450°F (<232°C) at PM control device inlet

MB/WW - mass burn waterwall MOD/SA - modular starved air

The discovery of CDD/CDF formation in full scale MWCs has prompted research in the laboratory to identify the parameters controlling low temperature CDD/CDF formation reactions. Bench scale experiments indicate that, under excess air conditions, CDD/CDF formation occurs on the surface of fly ash at temperatures ranging from approximately 200 to 400°C (392 to 752°F), with the maximum formation occurring near 300°C (572°F). [9] Conversely, research results have indicated that, when the same experiments were performed in an oxygen-deficient atmosphere, dechlorination of CDD/CDF compounds occurred.[10] The current thinking regarding these findings is that the formation process may involve catalytic reactions of organic precursor compounds with particulates containing metallic species such as copper chloride ($CuCl_2$). The bench scale studies indicate that the rate of CDD/CDF formation and/or chlorination is affected by a number of parameters, including temperature, residence time, catalyst effects, carbon content, oxygen concentration, and moisture. Results from these experiments provide information which can be transferred to full scale MWCs in order to develop control strategies for minimizing CDD/CDF formation.

Although many strategies for minimizing the reactions (e.g., catalyst poisons) remain to be investigated, it appears at this time that an initial control strategy is to minimize the particulate matter concentration and the flue gas residence time at temperatures were the rate of CDD/CDF formation is highest. If organic precursor materials leaving the combustor are minimized and if flue gas retention times and PM concentrations can be minimized in the 200-400°C (392-752°C) temperature range, it appears that the formation process can be minimized. Many existing MWCs currently operate flue gas cleaning equipment (ESPs) in this temperature window. The increased gas residence time and PM concentrations which occur in the ESP may be the primary cause of CDD/CDF formation, leading to increased emissions in the stack. Recent data from a full scale MWC confirm that high efficiency ESPs operating at temperatures below 250°C actually provide significant CDD/CDF removal.[11] Based on these considerations, a new component of good combustion practices was developed. The recommendation is to maintain PM control device inlet gas temperatures below 232°C (450°F).

3.0 MODEL PLANT PERFORMANCE ESTIMATES - MASS BURN COMBUSTORS

The following sections discuss the data and provide the rationale used to establish the baseline emission values in Table 1-2. The subsections are organized according to model plant combustion technology. The data used to establish baseline emissions for each model plant are compiled from emission tests performed at some of the newest plants in the existing MWC population. The emission tests can be separated into three distinct categories:

1. Compliance tests with sampling performed at the stack, downstream of flue gas cleaning equipment. In most cases these data were generated under optimal operating conditions at or near design steam load. In many cases process data such as temperatures and airflows were not recorded during testing.

2. Compliance tests with sampling performed concurrently at the inlet and outlet of the flue gas cleaning equipment. In most cases, limited process data were recorded, and the combustor operated at or near design steam load.

3. Parametric tests involving multi-point sampling under a variety of combustor and/or flue gas cleaning device operating conditions. Process data are usually well documented in these test reports.

The emissions data used in this analysis are presented in both tabular and graphical form. The data tables present multiple run averages reported for each test facility. Data measured in a parametric test are averaged and presented separately for each parametric operating condition. Combustor design and operating data are also included in the data summary tables. The data graphs present the emission levels for each sampling run, along with an average value for each testing condition.

Test reports that include emissions measured upstream of flue gas cleaning equipment provide the best data to evaluate combustion conditions. As a result, emission tests in categories 2 and 3 are the primary focus of this analysis. In some cases, data measured in the stack also provide information related to combustion conditions. When these data offer some insight into combustion conditions experienced during testing, they also

provide insight into combustion conditions experienced during testing; they are also included in the discussion of baseline emissions.

3.1 Conventional Mass Burn Waterwall MWCs

There are three conventional mass burn waterwall models included in this analysis. An inventory of planned and projected MWCs indicates that the majority of new facilities subject to the 111(b) NSPS will use mass burn technology.[12] The three model plants are representative of the projected population of MWCs, comprising two combustors at 100 tpd (91 Mg/day) each; two combustors at 400 tpd (364 Mg/day) each; and three combustors at 750 tpd (681 Mg/day) each.

3.1.1 Emissions Data for Existing Facilities

The baseline emissions are established based on review of available emissions data from some of the newest mass burn waterwall MWCs in the existing population. These units are considered to be representative of the planned and projected MWC population as of September 1988. Data are available for facilities using Von Roll, Martin, Detroit Stoker, and Riley Takuma technologies. These four system designs comprise more than 85 percent of the existing mass burn waterwall MWCs, and each manufacturer is expected to continue to be represented in the new MWC population. Descriptions of generic design and operating features associated with each of the system designs are included in EPA's Report to Congress on Municipal Waste Combustion.[4]

Table 3-1 presents a summary of emissions data for the facilities included in this analysis. Also included in Table 3-1 is information detailing the design and operation of each facility relative to the good combustion practice criteria which was developed for mass burn waterwall MWCs. When available, combustor operating conditions are presented as reported during the actual testing period. In cases where process operating data are not available, information has been supplied for a facility as reported in the Clean Air Act Section 114 questionnaire responses which were submitted to EPA by each existing facility.

TABLE 3-1. LARGE MASS BURN WATERWALL MWCS - PERFORMANCE ASSESSMENT
PAGE 1 OF 4

FACILITY		Millbury, MA
NUMBER OF UNITS - Flue gas cleaning equipment (FGC)		2 - SD/ESP
UNIT SIZE, tpd (Mg/day)		750 (682)
UNCONTROLLED EMISSIONS		
CDD/CDF (ng/dscm)		170
CO (ppmv)		38
PM (mg/dscm)		NA
CONTROLLED EMISSIONS		
CDD/CDF (ng/dscm)		59.2
CO (ppmv)		--
COMBUSTION PARAMETERS	GOOD COMBUSTION PRACTICE RECOMMENDATIONS	FACILITY DESIGN AND OPERATING CONDITIONS
DESIGN		
Temperature at fully mixed height	1800°F (982°C) mean	1500°F (816°C) at superheater inlet
Underfire air	At least 4 plenums along grate length	5 plenums along grate length
Overfire air capacity (not an operating requirement)	40% total air	At least 60% total air
Overfire air injector design	Complete penetration/ coverage	3 rows (2 front, 1 rear)
Auxiliary fuel capacity	As required to achieve temperature limits during start-up	Gas - 40% load
Exit gas temperature	<450°F (232°C) at PM control device inlet	435°F (224°C)
OPERATION		
Excess air	6-12% O2 (dry)	10.2% O2
Turndown	80-110% design load	Baseloaded - 100% ±3%; 66% minimum
Overfire air	Penetration and coverage of furnace cross section	40-50% total air
Start-up procedures	Auxiliary fuel to design temperature	Gas - 1500°F (816°C) at superheater inlet
Auxiliary fuel use	High CO, low temp; start-up/shutdown	Start-up/shutdown
VERIFICATION		
O2 levels	Monitor	Yes
CO	Monitor (<50 ppm at 7% O2)	Yes
Temperature	Monitor	Superheater inlet/ outlet
Air distribution	Monitor	OFA, UFA pressures
Exit gas temperature	Monitor	Yes

TABLE 3-1. LARGE MASS BURN WATERWALL MWCS - PERFORMANCE ASSESSMENT
PAGE 2 OF 4

FACILITY	Pinellas County, FL	Tulsa, OK
NUMBER OF UNITS - FGC	3 - ESP	3 - ESP
UNIT SIZE, tpd (Mg/day)	1050 (954)	375 (341)
UNCONTROLLED EMISSIONS		
CDD/CDF (ng/dscm)	69	--
CO (ppmv)	4	--
PM (mg/dscm)	225	--
CONTROLLED EMISSIONS		
CDD/CDF (ng/dscm)	132	36
CO (ppmv)	--	22
COMBUSTION PARAMETERS	FACILITY DESIGN AND OPERATING CONDITIONS	FACILITY DESIGN AND OPERATING CONDITIONS
DESIGN		
Temperature at fully mixed height	1700°F (927°C)	1400-1600°F (760-872°C) at superheater inlet
Underfire air	5 plenums along grate length	5 plenums per grate run
Overfire air capacity (not an operating requirement)	At least 25% total air	At least 40% total air
Overfire air injector design	2 rows (1 front, 1 rear)	NA
Auxiliary fuel capacity	None	None
Exit gas temperature	450-550°F (232-288°C)	375-515°F (191-263°C)
OPERATION		
Excess air	8-10% O2 at full load 9-11% O2 at minimum load	7-12% O2
Turndown	70-90% design load	72-100% load
Overfire air	25% of total air	20-40% total air
Start-up procedures	No auxiliary fuel	No auxiliary fuel
Auxiliary fuel use	None	None
VERIFICATION		
O2 levels	Yes	Yes
CO	No	Yes
Temperature	Furnace roof, superheater inlet/outlet	NA
Air distribution	OFA pressure, UFA damper settings	OFA, UFA pressures
Exit gas temperature	Yes	Yes

TABLE 3-1. LARGE MASS BURN WATERWALL MWCS - PERFORMANCE ASSESSMENT
PAGE 3 OF 4

FACILITY	Marion County, OR	Alexandria, VA
NUMBER OF UNITS - FGC	2 - SD/FF	3 - FI/ESP
UNIT SIZE, tpd (Mg/day)	275 (250)	375 (341)
UNCONTROLLED EMISSIONS		
CDD/CDF (ng/dscm)	43	--
CO (ppmv)	18	--
PM (mg/dscm)	205	--
CONTROLLED EMISSIONS		
CDD/CDF (ng/dscm)	1.39	53
CO (ppmv)	--	18
COMBUSTION PARAMETERS	FACILITY DESIGN AND OPERATING CONDITIONS	FACILITY DESIGN AND OPERATING CONDITIONS
DESIGN		
Temperature at fully mixed height	1400-1600°F (760-872°C) at superheater inlet	1400-1600°F (760-872°C) at superheater inlet
Underfire air	5 plenums per grate run	5 plenums along grate length
Overfire air capacity (not an operating requirement)	At least 40% total air	At least 40% total air
Overfire air injector design	3 rows	2 rows
Auxiliary fuel capacity	Gas - 30% load	Oil - 25% thermal load
Exit gas temperature	392°F (200°C)	375-505°F (191-263°C)
OPERATION		
Excess air	7-12% O2	7-12% O2
Turndown	75-105% design load	80-100% load
Overfire air	20-40% total air	20-40% total air
Start-up procedures	Gas to 1800°F (982°C)	On oil to 1400°F (760°C)
Auxiliary fuel use	Start-up/shutdown	Start-up/shutdown
VERIFICATION		
O2 levels	Yes	Yes
CO	No	Yes
Temperature	Middle and top of furnace	Furnace exit (superheater inlet)
Air distribution	OFA, UFA pressures	OFA, UFA pressures
Exit gas temperature	Yes	Yes

TABLE 3-1. LARGE MASS BURN WATERWALL MWCS - PERFORMANCE ASSESSMENT
PAGE 4 OF 4

FACILITY	Commerce, CA	Olmstead County, MN
NUMBER OF UNITS - FGC	1 - SD/FF	2 - ESP
UNIT SIZE, tpd (Mg/day)	350 (318)	100 (91)
UNCONTROLLED EMISSIONS		
CDD/CDF (ng/dscm)	27	--
CO (ppmv)	--	--
PM (mg/dscm)	4620	--
CONTROLLED EMISSIONS		
CDD/CDF (ng/dscm)	1.70	--
CO (ppmv)	16	31-54
COMBUSTION PARAMETERS	FACILITY DESIGN AND OPERATING CONDITIONS	FACILITY DESIGN AND OPERATING CONDITIONS
DESIGN		
Temperature at fully mixed height	1700°F (926°C) at superheater inlet	1700°F (926°C) furnace gas exit
Underfire air	6 plenums (2 per grate length)	3 plenums along grate length
Overfire air capacity (not an operating requirement)	40% total air	At least 35% total air
Overfire air injector design	2 front, 2 rear, 1 side	3 rows
Auxiliary fuel capacity	Gas - 100% load	Gas - 10% load
Exit gas temperature	480°F (249°C)	425°F (218°C)
OPERATION		
Excess air	10% O2 ±2%	7% O2
Turndown	70-101% design load	60-100% load
Overfire air	20-40% of total air	35% total air
Start-up procedures	On gas	On gas
Auxiliary fuel use	Start-up/shutdown	Start-up/shutdown
VERIFICATION		
O2 levels	Yes	Yes
CO	Yes	Yes
Temperature	Yes	Yes
Air distribution	OFA, UFA pressures	OFA, UFA pressures
Exit gas temperature	Yes	Yes

3.1.1.1 Millbury, Massachusetts

Wheelabrator Environmental Systems is the U.S. licensee of Von Roll technology. One of the newest Wheelabrator plants in operation is the Millbury, MA Resource Recovery Facility, which includes two 750 tpd (682 Mg/day) combustors. Each unit is equipped with a spray dryer and an ESP. The facility began operating in 1987 and underwent compliance testing in early 1988. In addition to performing stack testing for compliance purposes, emissions were measured at the spray dryer inlet location. Five CDD/CDF emission samples were gathered at the spray dryer inlet location at Unit #2, and average emissions were 170 ng/dscm CDD/CDF.[13] Individual runs ranged from 140 to 210 ng/dscm. Average CO emissions were 38 ppmv (4-hour average) during the five test runs. The average gas temperature at the inlet sampling location ranged from 429 to 442°F (221 to 228°C) during the five runs.

An assessment of the combustor design at Millbury indicates that the majority of design elements are in place to provide good combustion. Furnace temperatures are measured at the inlet and outlet of the superheater. The thermocouple at the superheater inlet location is approximately 35 feet (10.7 m) above the last point of overfire air injection, and a typical operating temperature at this location is 1500°F (816°C). Millbury has five individually controllable underfire air plenums along the length of the reciprocating grates. One design feature at Millbury that differs from older Von Roll systems is the overfire air capacity. The overfire air system has the capacity to supply 60 percent of total combustion air. The Millbury units operate with 40-50 percent of total air supplied as overfire air. Many Von Roll facilities constructed prior to Millbury operate with 30-40 percent of total airflow as overfire.

The majority of operation/control and verification elements representing good combustion practice are also in place at Millbury. The units typically operate at full capacity generating electricity, so low load operation is infrequent. All the recommended monitoring procedures are in place at Millbury.

3.1.1.2 Pinellas County, Florida

The Pinellas County MWC consists of three 1050 tpd (954 Mg/day) combustors, with Martin stokers and three-field ESPs. The #1 and #2 units

started up in 1983, and #3 commenced operation in 1986. Six ESP inlet/outlet CDD/CDF emission tests were conducted at Unit #3 in February and March 1987. Average inlet emissions were 69 ng/dscm and average CDD/CDF emissions in the stack were 132 ng/dscm.[8] Average flue gas temperatures at the ESP inlet location ranged from 523 to 553°F (273 to 289°C). Average PM and CO values measured at the ESP inlet were 0.98 gr/dscf (225 mg/dscm) and 4 ppmv, respectively. The CO emissions were measured concurrently with CDD/CDF testing, which was 3 hours' duration. Boiler #3 operated between 88 percent and 91 percent rated capacity during the six test runs, and O_2 concentrations varied from 6.9 to 7.7 percent (wet basis). Average furnace temperatures reported during testing varied from 1824°F (996°C) to 1923°F (1051°C), measured in the upper furnace. Underfire and overfire air plenum pressures were recorded and were fairly consistent during all of the runs. Actual airflow splits are not available.

The design of the Pinellas County plant meets the majority of criteria required for good combustion. However, Pinellas County does not have auxiliary fuel burners. In addition, the normal ESP operating temperature is approximately 500°F (260°C). The ESP temperature is assumed to have contributed to the increased CDD/CDF concentrations measured at the ESP outlet location. Based on the emission test results (low organics and CO levels), it is concluded that the unit achieves good mixing. The three units at Pinellas County are operated on a manual combustion control scheme, with the exception that steam production rates are automatically controlled. The majority of mass burn waterwall MWcs are equipped with fully automatic combustion controls. A manual control scheme may allow greater potential for combustion upsets to occur. With the exception that the units do not monitor CO continuously, Pinellas County has all of the verification measures in place to ensure good combustion practices are maintained.

3.1.1.3 Tulsa, Oklahoma

Emissions data from two other facilities using Martin designs were also used to establish baseline emission factors for the model plant. The first of these is the Tulsa, OK facility, which consists of three 375 tpd (341 Mg/day) combustor units. The facility began operating in 1986. Each of the units is equipped with an ESP. The ESP inlet gas temperature typically varies from 375 to 515°F (191 to 268°C). Available emissions data gathered for compliance purposes indicate average CDD/CDF emissions of 36 ng/dscm at the stack

location.[14] The flue gas temperature during testing was not included in the report. Emissions of CO averaged 22 ppmv at Unit #1 and 27 ppmv at Unit #2. The CO data were gathered separately from the CDD/CDF data, and are presented as 1-hour averages. There are no process data available in the test report to use in evaluating the combustor operating conditions. With the exception that Tulsa does not have auxiliary fuel, all of the requirements of good combustion are assumed to be achieved at this facility.

3.1.1.4 Marion County, Oregon

The Marion County, OR MWC consists of two 275 tpd (250 Mg/day) Martin combustors equipped with spray dryers and fabric filters. The units commenced operation in 1986. During stack compliance testing in September 1986, EPA performed three sampling runs at the boiler outlet (spray dryer inlet) location. Two of the three sampling runs were invalidated, but the results of the one successful run indicated an inlet CDD/CDF emission rate of 43 ng/dscm. In addition, inlet particulate emissions were 0.89 gr/dscf (2050 mg/dscm), and CO emissions were 18 ppmv (4-hour average).[15]

Process data were recorded during the compliance test at Marion County. The steam load was 97 percent of design load during CDD/CDF testing. Gas temperatures measured in the middle of the first furnace pass averaged 1741°F (949°C), and the average economizer outlet temperature was 392°F (200°C). Average exhaust gas oxygen concentrations were 9.5 percent, and the estimated overfire/underfire air ratio was 25/75. The Marion County units are equipped with auxiliary fuel burners that can provide 30 percent of thermal load. The units do not have continuous CO monitors.

EPA gathered an additional 14 unabated CDD/CDF samples at Marion County in February 1987. During all of the sampling runs, the boiler was operated at normal, full load conditions. Analysis was completed on seven of the runs. Four of the seven samples had acceptable spike recoveries and were full traverse samples. Three of the seven runs either were single point samples or were invalidated due to poor recoveries. The CDD/CDF values from the valid test runs ranged from 56 to 116 ng/dscm, with an average value of 99 ng/dscm.[16]

3.1.1.5 Alexandria, Virginia

The third new Martin facility, Alexandria, VA, consists of three 375 tpd (341 Mg/day) units that began operating in 1987. The system design includes in-furnace lime injection for acid gas control, and ESPs for PM control. Results of compliance testing performed at Unit #1 in December 1987 indicated a three-run average of 53 ng/dscm CDD/CDF and 18 ppmv of CO (3-hour average) in the stack.[17] Limited process data are included in the compliance test report. The boiler reportedly operated at between 98 and 99 percent design steam load during the three runs, and average O_2 concentrations were 9.5 percent. The furnace temperature was measured at an unspecified furnace exit location with an unshielded thermocouple. The average temperature during the three runs was 1651°F (899°C), 1664°F (907°C), and 1642°F (894°C). The test report authors state that the measurement method "should be regarded as being relatively accurate; i.e., lower than the actual temperature by approximately 150-200°F, but precise." The average stack temperature was reported to be 342°F (172°C) while sampling, so it is judged that the ESP temperature was below 450°F (232°C). Although the existing data base does not provide a basis for estimating the effect of dry lime furnace injection on CDD/CDF, the emission levels are typical of those measured at other Martin systems, that do not use acid gas controls.

The facility is judged to satisfy the majority of criteria included in the good combustion practice recommendations. The gas temperatures at the superheater inlet are reported to vary from 1400°F (760°C) to 1600°F (871°C). The plant has an auxiliary fuel source (oil), and the firing capacity is 25 percent of boiler load.

3.1.1.6 Commerce, California

The Commerce, CA, MWC consists of one 350 tpd (318 Mg/day) unit with Detroit Stoker grates and a Foster Wheeler boiler. The unit is equipped with a spray dryer/fabric filter. Commerce was also the first MWC in the U.S. to use thermal de-NO_x controls. The facility underwent an emissions test in 1987 for compliance purposes. The CDD/CDF emissions data were measured according to the draft California Air Resources Board (CARB) Modified Method 5 (semi-VOST) protocol. Two test runs were conducted at the stack while burning the largely commercial waste normally received at the facility. A third test run

was conducted with simultaneous measurement at the boiler exit and stack while burning a residential refuse brought in from Long Beach, CA, specifically for the test. Steam load was reduced from full load to 80 percent of capacity during the inlet/outlet sampling. During the one test run that was conducted at the spray dryer inlet, 27 ng/dscm CDD/CDF was measured. Inlet PM and CO emissions were 1.56 gr/dscf (3590 mg/dscm) and 16 ppmv (1-hour average), respectively.[18]

The amount of process data included in the emissions test report is fairly limited. Steam load varied from 80 to 103 percent of capacity during the test. The thermal de-NO_x system was operational throughout the testing period except for one test run when the NO_x levels were measured without ammonia injection. This control system demonstrated NO_x reduction in excess of 40 percent. The report contains no information on combustion air operating levels.

The Commerce facility has all of the design components of good combustion in place. It is judged that the 1700°F (927°C) superheater inlet temperatures correspond to a temperature at the fully mixed height which meets the good combustion recommendations. The operation of the facility is maintained by a fully automatic control system. The unit generates electricity, operating at full load whenever possible. All of the verification measures are in place to monitor continuous performance and ensure good combustion.

3.1.1.7 Olmstead County, Minnesota

The last mass burn waterwall MWC included in this discussion is the Olmstead County, MN facility, which began operating in March 1987. The facility consists of two 100 tpd (91 Mg/day) Riley-Takuma MWCs. Although CDD/CDF emissions data are not available for the facility at this time, the plant does monitor CO continuously, and average reported values are 31-54 ppmv at 7 percent O_2 (averaging time not reported).[19] The testing program at Olmstead County was a characterization test to determine the operating and emissions performance of one of the units prior to undertaking a gas co-firing performance evaluation. Sampling was performed at multiple points in the furnace for O_2, CO_2, CO, and NO_x. A series of 21 tests were performed with variations in load, combustion airflow, and air distribution. Furnace

temperatures were measured by suction pyrometry during each test. Temperature profiles were also measured at the economizer outlet location.

One of the main conclusions in the study was that the use of overfire air contributes to a reduction in CO emissions and at the same increases NO_x levels. The highest NO_x emissions (191 ppmv) and the lowest CO emissions (31-54 ppmv) occurred when overfire air was operated at 33 percent of total air, and the lowest NO_x (70 ppmv) and highest CO (123 ppmv) occurred when overfire air was turned off.

The majority of good combustion elements are in place at Olmstead County. However, there are only three plenums along the grate length, which is typical for smaller capacity systems. The auxiliary fuel capacity is lower than specified by the guidelines (10 percent versus 60 percent of full load), but this will not affect baseline operating conditions. The low economizer exit gas temperatures [typically 425°F (218°C)] should minimize the potential for formation of CDD/CDF in the ESP.

3.1.2 Model Plant Baseline Emissions

The data used to establish baseline CDD/CDF emissions for mass burn waterwall model plants are plotted in Figure 3-1. The data include values for each individual sampling run. Facility averages are also plotted when multiple runs are available. Five of the seven data sets include uncontrolled emissions measured upstream of flue gas cleaning equipment. Average emissions range from 27 ng/dscm (one run) at Commerce to 170 ng/dscm (5 runs) at Millbury. Two of the data sets consist of controlled emissions measured in the stack downstream of an ESP. Average emissions reported for these two plants (Tulsa and Alexandria) are 36 ng/dscm and 53 ng/dscm, respectively. The ESP operating temperature was not specified for Tulsa during the test runs. The stack temperature at Alexandria was reported to be 342°F (172°C) during testing, so it is assumed that the ESP operated at or below 400°F (204°C), and that some amount of CDD/CDF removal occurred in the ESP.

The available uncontrolled data indicate that three of the four plants tested achieved CDD/CDF emissions below 100 ng/dscm. However, two of the data sets consist of a single sampling run, and these single runs may not accurately represent an average CDD/CDF emission level. This is verified by

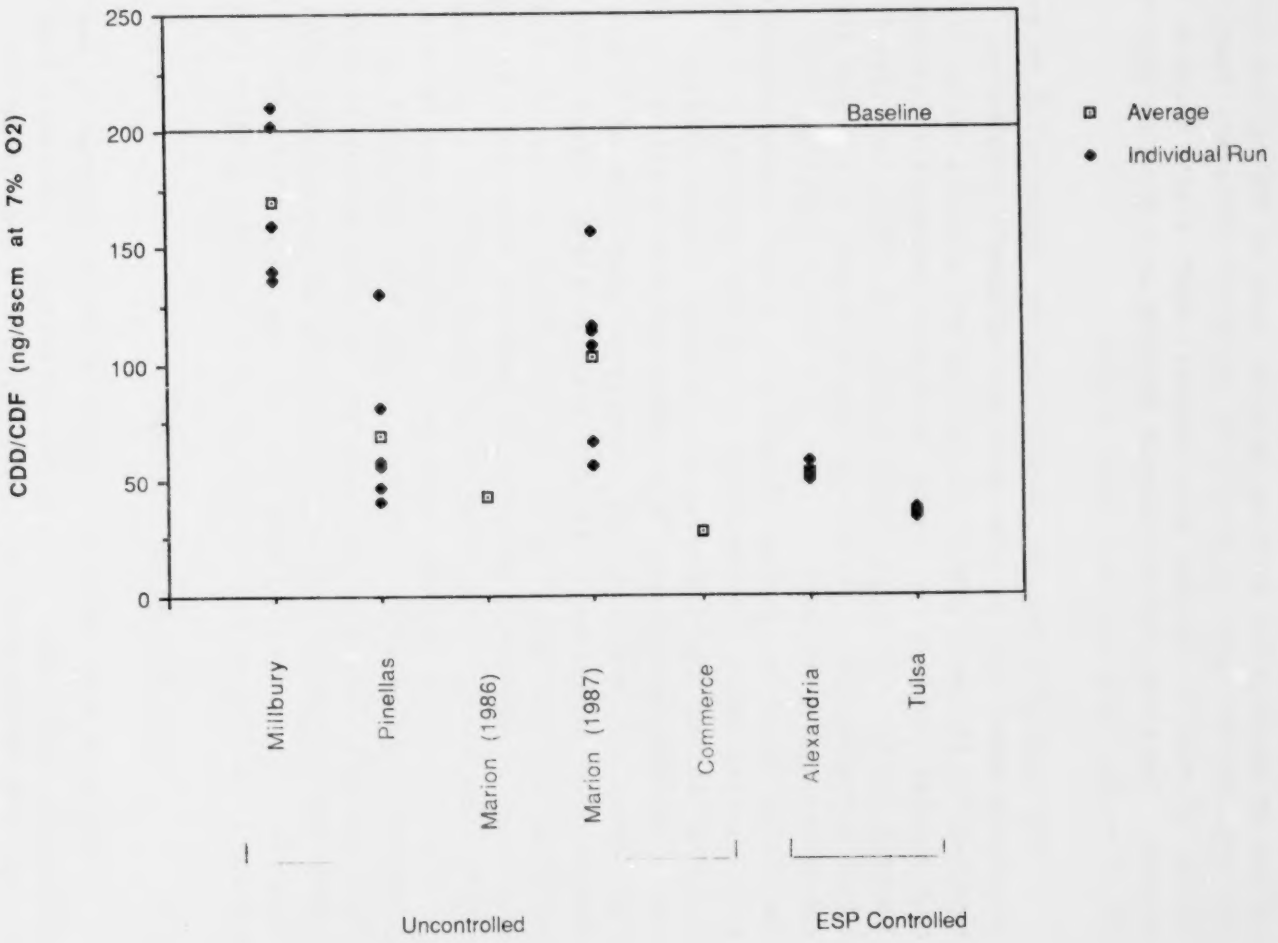

Figure 3-1. Mass Burn Waterwall Baseline Determination

the multiple runs obtained at Marion County in 1987. Based on the available data in Figure 3-1, it is assumed that all seven of the facilities are able to achieve an uncontrolled baseline emission level of 200 ng/dscm CDD/CDF. There are insufficient data available to establish different baseline emission levels for each of the mass burn waterwall model plants based on manufacturer or size. Therefore, 200 ng/dscm was selected as a baseline emission level for all three mass burn waterwall model plants.

The available data on CO emissions and uncontrolled PM emissions are relatively consistent for the mass burn waterwall population. The CO data reported for the seven plants included in this analysis varied from 4 ppmv (3-hour average) at Pinellas County to 43 ppmv (unspecified averaging time) at Olmstead County. Tulsa and Commerce report CO levels less than 30 ppmv with a 1-hour averaging time. Alexandria reports 18 ppmv on a 3-hour averaging time, and Marion County reports 18 ppmv on a 4-hour averaging time. All of the facilities tested can achieve 50 ppmv on a 4-hour average, which was selected as a baseline value. Uncontrolled particulate emissions will vary according to boiler design, air distribution, and waste characteristics. For example, facilities that operate with high underfire/overfire air ratios or relatively high excess air levels may entrain greater quantities of PM and have higher uncontrolled emissions. Boilers with multiple passes that change the direction of flue gas flow in the convective section may remove greater quantities of entrained PM prior to entering flue gas cleaning equipment. Lastly, the physical properties of waste being fed to a unit may impact the amount of PM that becomes entrained. Despite these factors, a nominal uncontrolled PM emission rate from a mass burn waterwall MWC is 2 gr/dscf (4600 mg/dscm). The available data for the units discussed above ranges from 0.89 gr/dscf (2050 mg/dscm) at Marion County to 1.56 gr/dscf (3660 mg/dscm) at Commerce. It is anticipated that all new mass burn waterwall MWCs will achieve a baseline uncontrolled PM emission rate of 2 gr/dscf (4600 mg/dscm).

3.2 Split Flow Refractory MWCs

The mass burn refractory model plant is assumed to use the Volund combustion technology. The Volund combustor is characterized by a split furnace flow design which may be configured in two different ways (see Figures 3-2 and 3-3). The Volund systems are designed either with a refractory arch which splits the flow, or with a flue gas overpass and a rotary kiln. The kiln arrangement is generally used for medium and large size units [greater

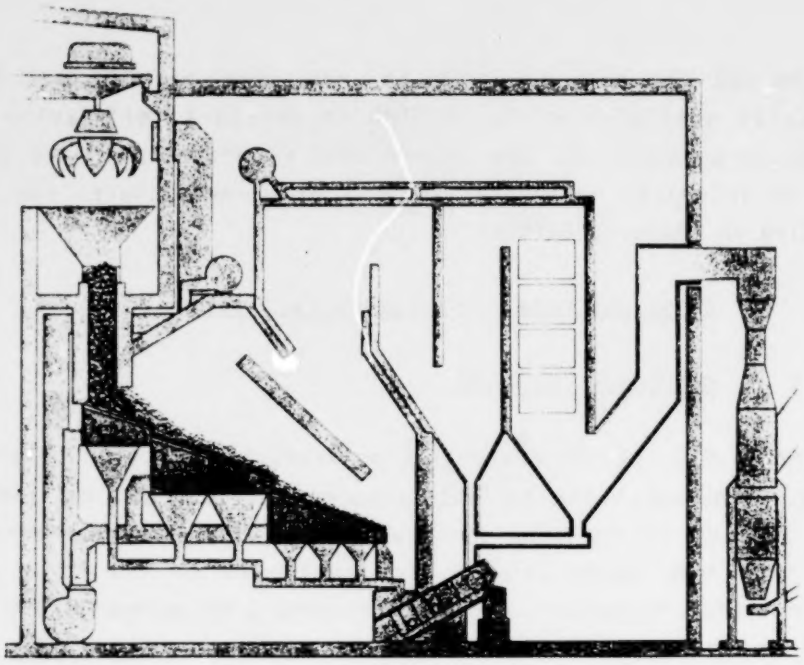

Figure 3-2. Volund Split Flow Furnace

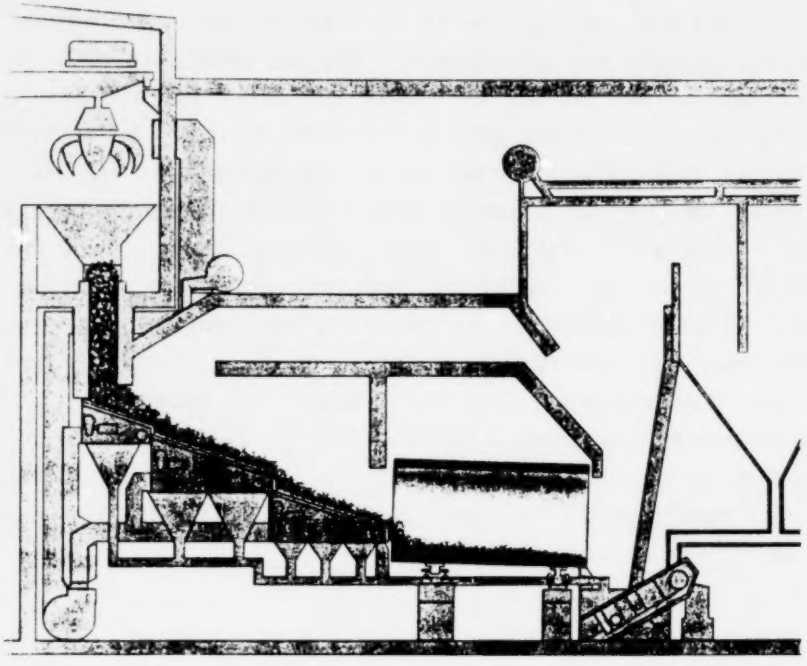

Figure 3-3. Volund Split Flow Furnace with Rotary Kiln

than 150 tpd (136 Mg/day)] while the refractory arch is used for small units. If locally available waste is high in moisture, difficulty achieving good burnout is possible and the rotary kiln is preferred. The kiln exposes the waste to increased residence times at high temperatures and oxygen content, resulting in improved burnout.

3.2.1 Emissions Data for Existing Facilities

3.2.1.1 McKay Bay, Florida

McKay Bay, FL, is one operating facility in the U.S. which uses the new Volund technology. The facility consists of four 250 tpd (227 Mg/day) units which use the rotary kiln configuration. The plant commenced operation in 1985, and compliance testing was performed on the four units in 1986. Uncontrolled particulate emissions averaged 1.86 gr/dscf (4350 mg/dscm) and CO emissions averaged 32 ppmv (individual units achieved 30, 35, 32, and 32 ppmv).[14] Emissions of CDD/CDF were not reported for this plant. Very limited process data are available for the test.

Table 3-2 summarizes recommended good combustion practices for refractory wall MWCs using the split flow design. One specific requirement that differs between refractory wall MWCs and waterwall MWCs is the excess air operating range. Refractory wall MWCs typically operate at higher excess air levels than waterwall MWCs due to the need to provide furnace cooling. An evaluation of available information on the McKay Bay, FL, facility indicates that several of the good combustion practice design criteria are not met, including requirements for auxiliary fuel use and for exit gas temperatures. The ESPs at McKay Bay typically operate near 550°F (288°C), so potential exists for CDD/CDF formation to occur in the control devices. In addition, the plant does not monitor CO. The combustion control scheme is based on steam flows, temperatures, and air flows. The secondary air level controls the temperatures exiting the furnace. Although combustor operating temperatures are not specified, it is assumed that the units meet the temperature requirements for good combustion. The McKay Bay units typically operate at 60-135 percent excess air.

TABLE 3-2. SPLIT FLOW REFRACTORY MWCS - PERFORMANCE ASSESSMENT

FACILITY		McKay Bay, FL
NUMBER OF UNITS - FGC		4 - ESP
UNIT SIZE, tpd (Mg/day)		250 (227)
UNCONTROLLED EMISSIONS		
CDD/CDF (ng/dscm)		Not Available (NA)
CO (ppmv)		32
PM (mg/dscm)		4280
CONTROLLED EMISSIONS		
CDD/CDF (ng/dscm)		NA
CO (ppmv)		--
COMBUSTION PARAMETERS	GOOD COMBUSTION PRACTICE RECOMMENDATIONS	FACILITY DESIGN AND OPERATING CONDITIONS
DESIGN		
Temperature at fully mixed height	1800°F (982°C) mean	NA
Underfire air	At least 4 plenums along grate length (not including kiln)	3 plenums
Overfire air capacity (not an operating requirement)	40% total air	Sidewall air
Overfire air injector design	Complete penetration/ coverage	Quantity not specified
Auxiliary fuel capacity	As required to achieve temperature limits during start-up	None
Exit gas temperature	<450°F (232°C)	550°F (288°C)
OPERATION		
Excess air	6-14% O2 (dry)	8-12% O2
Turndown	80-110% design load	Unknown
Overfire air	Penetration and coverage of furnace cross section	Unknown
Start-up procedures	Auxiliary fuel to 1800°F (982°C)	No auxiliary fuel
Auxiliary fuel use	High CO, low temp; start-up/shutdown	No auxiliary fuel
VERIFICATION		
O2 levels	Monitor	No
CO	Monitor (<100 ppmv at 7% O2))	No
Temperature	Monitor	Yes
Air distribution	Monitor	NA
Exit gas temperature	Monitor	NA

3.2.1.2 Nykoping, Denmark

A second set of emissions testing data is available from a Volund plant located in Nykoping, Denmark.[20] This facility includes two units with a combined capacity of 168 tpd (153 Mg/day). The units, which began operating in 1983, burn a mixture of domestic and non-hazardous industrial waste. Each unit uses the refractory arch split flow configuration rather than a refractory kiln. The majority of the combustion gases pass above the furnace arch and are mixed with gases from the burnout grate. The units are equipped with waste heat boilers, ESPs, and automatic combustion controls which regulate furnace temperatures and steam production rates.

The emissions testing performed at Nykoping included CDD/CDF stack sampling during start-up, normal operation, and variable boiler loads. Flue gas oxygen concentrations were maintained between 7.4 and 9.7 percent, and average furnace temperatures were approximately 940°C (1724°F). Temperatures were measured above the transverse arch where the flow streams converge and mix. Although the data are not tabulated for all runs, a typical CDD/CDF emission level was reported to be 246.5 ng/Nm^3 (sum of all CDD/CDF corrected for spike recoveries).[20] Graphical presentations of CO emissions are included in the test report, but no values are tabulated for specific sampling runs. It appears from the graphs that the units operate at CO levels between 50 and 200 ppmv. The authors of the test report concluded from the emission results that mixing in the furnace has an important impact on the destruction of CDD/CDF, and that concentrations of CO in the flue gases at well designed plants can be used as a parameter for monitoring and control. There is insufficient information available to assess the design and operation of the Nykoping unit with the good combustion practice criteria, but the furnace temperatures and oxygen levels reported are indicative of good combustion conditions. The ESP operating temperature was not reported at Nykoping.

3.2.2 Model Plant Baseline Emissions

Based on the limited data available from the McKay Bay and Nykoping MWCs, a baseline emission level of 300 ng/dscm CDD/CDF was established for the model plant. Although all four of the combustors at McKay Bay achieved CO emissions lower than 50 ppmv, a graphical presentation of CO data from Nykoping indicates slightly higher levels during optimum combustion

conditions. Therefore, baseline CO emissions were established at 100 ppmv. The limited data available from the McKay Bay units supports an uncontrolled particulate emission level of 2 gr/dscf (4600 mg/dscm).

3.3 Rotary Waterwall MWCs

The O'Connor Combustor Corporation was purchased by Westinghouse in 1986. The Westinghouse/O'Connor system design is unique; it includes a rotary waterwall cylinder consisting of alternating watertubes and perforated steel webs (i.e. a cylindrical, perforated membrane waterwall). Waste is fed to the combustor by a dual ram feeder, and preheated combustion air is delivered through the perforated webs by way of six windboxes located beneath the barrel. The rotary section terminates within a waterwall boiler where bottom ash is discharged and combustion gases pass through the boiler to produce steam.

The first O'Connor MWC in the U.S. commenced operation in 1980 in Gallatin, TN.[21] Since Westinghouse purchased the O'Connor system, they have started up two new facilities (Bay County, FL, and Dutchess County, NY). Several more plants are in planning, permitting, or construction stages. Parametric testing results obtained from Bay County and Gallatin have influenced some aspects of Westinghouse's approach to designing new facilities. For example, the Gallatin facility originally included rows of overfire (tertiary) air ports in the radiant section of the boiler above the rear of the rotary portion. In addition, an afterburning grate was located at the discharge of the rotary section. Following field testing in 1984, the testing engineers recommended that combustion air be eliminated from these locations in the system. These modifications were made, but the air supplies were reinstated after Westinghouse purchased O'Connor. Particulate, metals, and CO emissions data are available from Gallatin, but they are not included in this analysis because the facility is not representative of new Westinghouse/O'Connor technology.

At Bay County the rotary portion of the combustor was designed with a tapered end that protrudes several feet into the radiant section of the boiler. The new Westinghouse/O'Connor plants are designed with a constant diameter barrel; the end of the barrel is flush with the waterwalls rather than extending into the radiant section of the boiler. In addition, the

afterburning grate is a water cooled Detroit Stoker vibrating grate rather than a stationary design.

3.3.1 Emissions Data for Existing Facilities

Initial continuous CO measurements made at Bay County indicated average emissions of 100-200 ppmv. Westinghouse concluded that these relatively high CO levels were due to (1) a low temperature zone below the protruding barrel where mixing was not completed and (2) smoldering of ash on the afterburning grate.[22] Modifications were made to the combustion air distribution system, including the addition of rows of tertiary air nozzles in the front and rear boiler walls above the rotary combustor (similar to those originally in place at Gallatin) and a small percentage of total air supplied beneath the afterburning grate. These modifications reduced CO emissions to below 100 ppmv. Results of continuous CO monitoring data from Bay County are reported to be 57 ppmv (3-hour average), 64 ppmv (7-hour average), and 83 ppmv (9-hour average) during three separate testing periods.[23] Westinghouse has gathered uncontrolled and stack CDD/CDF data at Bay County, but the results have not yet been reported.

The available Bay County emissions data and an assessment of combustor performance are presented in Table 3-3. The good combustion practices for rotary waterwall combustors require technology-specific application. For example, the requirement for four separately adjustable air plenums includes the 3x2 arrangement of windboxes in the rotary section of the unit and a source of combustion air under the afterburning grate below the combustor discharge. In addition, the O'Connor design typically operates at lower excess air levels (40-80 percent) than conventional mass burners (40-130 percent). However, the basic approach to combustion control of emissions is the same: good mixing is required at sufficient temperatures to destroy organic emissions, and the potential for downstream formation of CDD/CDF must be minimized.

3.3.2 Model Plant Baseline Emissions

The Bay County, FL CDD/CDF emission results have not yet been reported; thus, no measured data are currently available to support baseline emission estimates from Westinghouse/O'Connor combustors. Therefore, baseline uncontrolled CDD/CDF emissions of 300 ng/dscm were established for the 111(b)

TABLE 3-3. MASS BURN ROTARY WATERWALL MWCS - PERFORMANCE ASSESSMENT

FACILITY		Bay County, FL
NUMBER OF UNITS - FGC		2 - ESP
UNIT SIZE, tpd (Mg/day)		255 (232)
UNCONTROLLED EMISSIONS		
CDD/CDF (ng/dscm)		Not Available (NA)
CO (ppmv)		60-80
PM (mg/dscm)		NA
CONTROLLED EMISSIONS		
CDD/CDF (ng/dscm)		NA
CO (ppmv)		60-80
COMBUSTION PARAMETERS	GOOD COMBUSTION PRACTICE RECOMMENDATIONS	FACILITY DESIGN AND OPERATING CONDITIONS
DESIGN		
Temperature at fully mixed height	1800°F (982°C) average	1400°F (760°C) at inlet to convective section
Underfire air	4 plenums, including one at burnout grate	4 plenums (one at afterburning grate)
Overfire air capacity	Sum of secondary and tertiary air designed to supply 40% of total air	Confidential
Tertiary air design	Complete coverage and penetration	Confidential
Auxiliary fuel capacity	That required to achieve temperature limits during start-up	Oil - 40% load
Exit gas temperature	<450°F (232°C)	450°F (232°C)
OPERATION		
Excess air	3-9% O2 in flue gas (dry)	5-57% O2 (wet)
Turndown	80-110% design load	30% minimum
Tertiary air	Complete coverage and penetration	Not achieved
Start-up procedures	Auxiliary fuel to design temperature	Use steam preheat from adjacent combustor
Auxiliary fuel use	High CO, low temp; start-up/shutdown	NA
VERIFICATION		
O2 levels	Monitor	Yes
CO	Monitor (<100 ppmv at 7% O2)	Yes
Temperature	Monitor	Yes
Air distribution	Monitor	UF, OF, tertiary
Exit gas temperature	Monitor	Yes

model plant based on engineering judgement. Based on the results reported from Bay County, baseline CO emissions were established at 100 ppmv. Uncontrolled PM emissions are assumed to be 2 gr/dscf (4600 mg/dscm), consistent with uncontrolled PM measurements at conventional mass burn waterwall facilities.

3.4 Modular Excess Air MWCs

The population of planned and projected modular excess air MWCs consists of several distinctly different designs. The three design types identified with facilities in planning, permitting, or construction stages include:

- Vicon/Enercon (7 known projects)
- Cadoux (3)
- Basic (1)

All three of these designs utilize multiple combustion chambers; Vicon/Enercon and Basic also employ flue gas recirculation (FGR). One key difference in the physical designs is that the Basic primary chamber is a membrane waterwall, while Vicon/Enercon and Cadoux use refractory wall combustors with separate waste heat boilers.

3.4.1 Existing Facilities Emissions Data

3.4.1.1 Pittsfield, Massachusetts

There are three sets of CDD/CDF data available from modular excess air MWCs. The first data set includes the parametric test results obtained from a research program conducted at the Vicon/Enercon facility in Pittsfield, MA.[6] A facility equipment schematic is shown in Figure 3-4. The plant comprises three 120 tpd (109 Mg/day) units and two waste heat boilers. Testing was performed with two of the three units in operation, which is the normal operating condition for the facility. Each boiler exhausts to an electrified granular bed (EGB) filter for removal of PM. The EGBs typically operate at 475°F (246°C). Organic emissions, including CDD/CDF, PCBs, chlorophenols, and chlorobenzenes, were measured over a large range of operating conditions and while firing various fuels (MSW, PVC spiked MSW, PVC free waste).

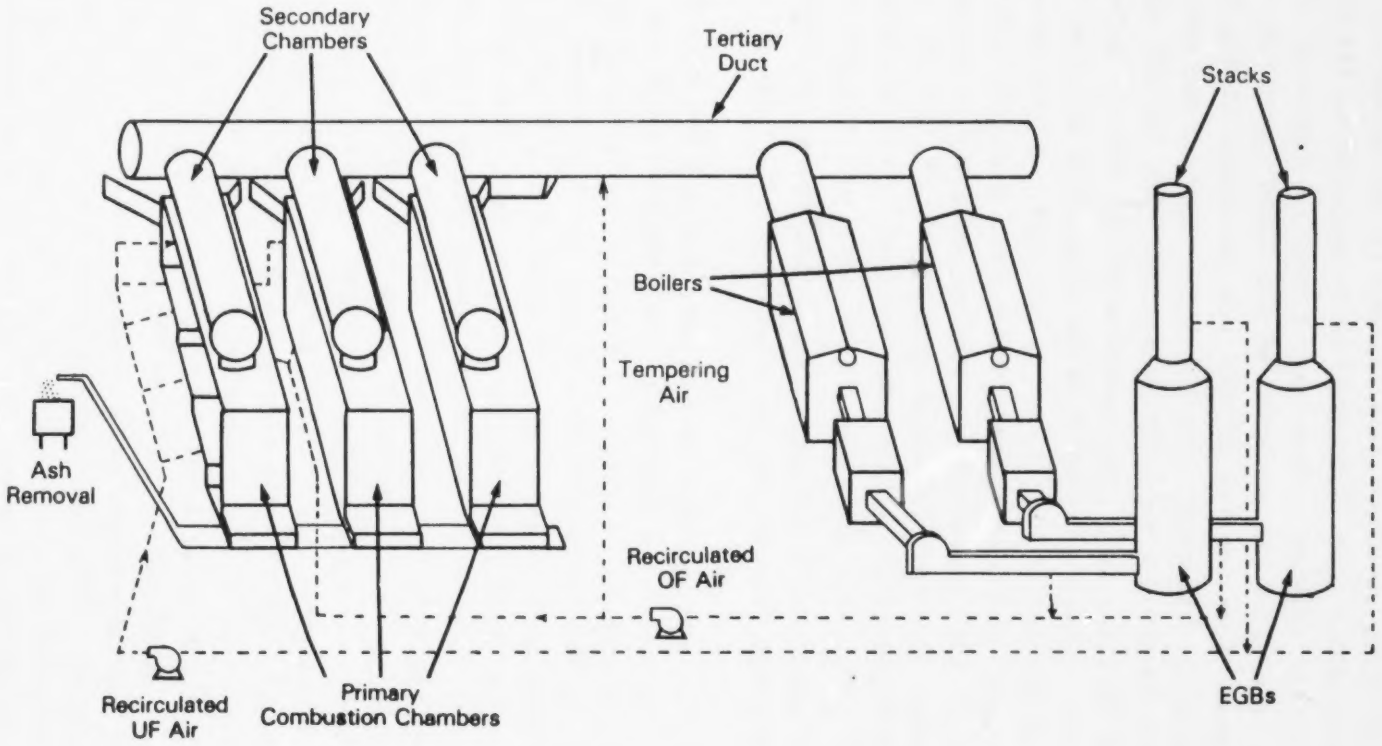

Figure 3-4. Pittsfield, MA Modular Excess Air MWC

Table 3-4 presents a summary of average CDD/CDF and CO emissions reported for each operating condition investigated in the parametric test. The temperature specified for each test condition is measured at the exit of the secondary combustion chamber. Each test condition consisted of two individual sampling runs, with the exception of the 1400°F condition, which included only one run. Sampling for CDD/CDF was performed at the boiler outlet for each operating condition. CDD/CDF stack sampling was performed during two conditions (1800°F-MSW and 1800°F-MSW + PVC), and CDD/CDF samples were gathered at the tertiary duct (just upstream of the boiler) during the eight other conditions. Carbon monoxide emission levels were measured in the tertiary duct and at the boiler outlet during all runs. Fairly extensive process monitoring was performed during this test program, including measurement of airflows and temperatures at various locations in the system. Testing was performed for the suspected precursors of CDD/CDF (PCBs, chlorobenzenes, chlorophenols). Continuous monitors were maintained to measure O_2, CO_2, CO, SO_2, NO_x, HCl, and THC at various locations in the system. Control of combustion temperatures was maintained by modulation of feed rates and recirculated flue gas and, to a lesser extent, fresh airflows.

One of the main conclusions made in the data analysis was that CDD/CDF emission levels were not generally affected by the different waste characteristics evaluated in the program. However, as expected, emissions of HCl were noticeably affected by PVC content in the waste. In most cases, CDD/CDF concentrations increased at each sampling location as the flue gases passed through the system. The temperatures at the tertiary duct sampling location are nearly equivalent to the target values specified in each sampling condition. The sampling point was upstream of the flue gas recirculation injection point (see Figure 3-4). The amount of recirculated (tempering) air injected into the tertiary duct controls the boiler inlet gas temperature, which varied from approximately 1100°F (593°C) during the 1300°F-MSW condition to approximately 1400°F (760°C) during normal operating conditions (1800°F-MSW). The average boiler outlet gas temperature varied from 460 to 540°F (255 to 282°C). Therefore, the flue gases pass through the critical CDD/CDF formation temperature (approximately 300°C) in the boiler. This is reflected by the increases in CDD/CDF concentrations between the tertiary and boiler outlet sampling locations. This result was observed during six of the eight conditions. The formation rate appears to be higher than actually may be occurring, because the gas stream at the boiler outlet location contains gases recirculated from ahead of the APCD. Increased concentrations of CDD were

TABLE 3-4. PITTSFIELD, MA MODULAR EXCESS AIR MWC EMISSIONS TEST DATA

TESTING CONDITION	TERTIARY DUCT		BOILER OUTLET		STACK
	CDD/CDF (ng/dscm)	CO (ppmv)	CDD/CDF (ng/dscm)	CO (ppmv)	CDD/CDF (ng/dscm)
1300°F - MSW	112	201	403	148	-
1400°F - MSW	18	44	40	22	-
1550°F - MSW	15	9	57	15	-
1550°F - MSW + H2O	57	17	21	14	-
1800°F - MSW	-	4	94	12	154
1800°F - MSW, low O2	76	7	165	9	-
1800°F - MSW + PVC	-	6	148	7	261
1800°F - PVC free	31	1	71	9	-
1800°F - PVC free + PVC	14	6	87	13	-
1800°F - PVC free + H2O	48	8	28	7	-

measured between the two sampling points during all but two conditions (1550°F-MSW + H_2O, and 1800°F-PVC free + H_2O). The influence of water on the CDD/CDF formation mechanism must be investigated further in order to draw conclusions related to this observation at Pittsfield. No PM sampling was performed during any of the test runs. However, waste moisture content may have reduced the amount of PM that was entrained in the fly ash and available for downstream catalytic reactions to occur. A normal sootblowing cycle was reportedly performed for the boiler during each 4-hour sampling run. The facility was reportedly scheduled for an annual maintenance shutdown 2 weeks after the completion of testing; the condition of the plant was considered normal during testing (no special maintenance was performed prior to initiating the program).

Paired runs gathered during normal operating conditions (1800°F-MSW) provided an average CDD/CDF emission rate of 94 ng/dscm at the boiler outlet (154 ng/dscm at the stack). At the 1500°F-MSW test condition, the total CDD/CDF emissions averaged 57 ng/dscm at the boiler outlet (no stack measurements available). As secondary chamber temperatures were decreased to 1300°F, the average CDD/CDF emission rate increased to 403 ng/dscm at the boiler outlet. The low temperature runs were performed for experimental purposes and are not expected to be encountered during normal operating conditions.

Stack testing was performed at Pittsfield during two operating conditions (1800°F-MSW and 1800°F-MSW + PVC). Concentrations of CDD/CDF increased by 64 and 76 percent, respectively, from the boiler outlet location to the stack. Average boiler outlet gas temperatures ranged from 472 to 536°F (250 to 280°C) during these four sampling runs.

During all the aforementioned testing runs, CO emissions were measured, and average emission levels at the boiler outlet did not exceed 22 ppmv (4-hour average) except when operating at 1300°F, when 148 ppmv was measured.

The extensive emissions and process data generated at Pittsfield demonstrate that sufficiently high temperatures and adequate mixing conditions are present to minimize CDD/CDF and CO emissions at normal operating conditions. The low emission levels measured at Pittsfield confirm that the units have good combustion practices in place.

3.4.1.2 Pigeon Point, Delaware

A second data set available for the Vicon/Enercon facility is Pigeon Point, DE. This plant comprises five 120 tpd (109 Mg/day) units that fire a mixture of MSW and RDF, with ESP controls. The compliance test at Pigeon Point was conducted in two phases. Phase I consisted of HCl, SO_3, CO, and PM measurements made in the stack. Particulate testing was also performed at the ESP inlet location for all four units. Phase II involved stack sampling for CDD/CDF and heavy metals (Pb, Hg, Be, Ni, As, Cd, Cr).

The three-run average uncontrolled PM levels for each of the four flues tested were 1.03 gr/dscf (2370 mg/dscm), 1.03 gr/dscf (2370 mg/dscm), 0.90 gr/dscf (2070 mg/dscm), and 0.43 gr/dscf (990 mg/dscm).[24] One of the flues discharges gases from two combustors. Average flue gas temperatures entering the ESP ranged from 393 to 433°F (200 to 223°C). Due to the low particulate concentrations and the low operating temperature, it is doubtful that substantial CDD/CDF formation would occur in the ESP.

Three CDD/CDF sampling runs were performed in the stack of unit #2. The average emissions were reported to be 105 ng/dscm.[24] The average stack temperature was reported to be 374°F (190°C). The CO data included in this test were measured by ORSAT analysis and were reported to be 0.0 percent by volume. The CDD/CDF concentrations in the ESP fly ash are also reported for each sampling run. Very limited process data are available to use in characterizing the operation of the Pigeon Point facility during testing. The plant attempts to feed a mixture of 5 pounds RDF per pound of MSW, and it appears that this ratio was maintained during the tests. Based on the assumption that the combustor design and operation are similar to that at Pittsfield, it can be concluded that good combustion practices are in place at Pigeon Point. The measured emission levels from Pigeon Point and Pittsfield confirm the good performance of the Vicon/Enercon design. The consistency of the CDD/CDF data with that measured at Pittsfield also indicate that CDD/CDF emission levels are more dependent on combustion technology than on waste feed characteristics.

3.4.1.3 Alexandria, Minnesota

A third data set is available from a facility using the Cadoux design. Emissions testing was performed at the Pope/Douglas Waste-to-Energy Facility

in Alexandria, MN, in July 1987. This plant began operating in May 1987 using two 38 tpd (35 Mg/day) Cadoux modular excess air combustors. Both units are equipped with an ESP. Average CDD/CDF emissions at the stack were reported to be 446 ng/dscm.[25] The continuous monitoring results indicated that average CO emissions were 24 ppmv (1-hour average). The average flue gas temperature at the ESP inlet sampling location ranged from 490 to 503°F (254 to 262°C). These values are in the temperature window where CDD/CDF formation has been observed. Therefore, it is assumed that CDD/CDF at the ESP inlet was lower than the concentrations in the stack. The CDD/CDF and CO measurements were made on Unit #2. Particulate sampling was also performed in the stack of both units.

Thermocouples were installed in Unit #1 at two locations in the primary combustion chamber. The first was located on the side wall at the grate level, and the second was in the top of the chamber. The average temperature at the grate varied from 1300 to 1650°F (704 to 899°C) and the temperature in the upper furnace ranged from 1770 to 1990°F (965 to 1088°C). Charge rates were measured during the testing program and both units were operating between 100 and 145 percent rated capacity. Oxygen levels were also measured in an eight-point traverse at the combustor outlet, and average concentrations were 14.8 percent at Unit #1 and 12.8 percent at Unit #2. These values equate to approximately 245 percent and 160 percent excess air, respectively.

3.4.2 Model Plant Baseline Emissions

Baseline emissions for the model plant are based largely on the performance of the two Vicon/Enercon MWCs at Pittsfield and Pigeon Point. The emissions data from these systems and the Cadoux facility at Pope/Douglas County are plotted together in Figure 3-5. The only data included from the Pittsfield parametric test are those runs which took place under normal operation, firing 100 percent MSW. The off spec, low temperature runs are not expected to be encountered in normal operation. Baseline emissions are assumed to be 200 ng/dscm CDD/CDF and 50 ppmv CO. Uncontrolled PM emissions are assumed to be 2 gr/dscf (4600 mg/dscm), which is an average value for mass burn systems.

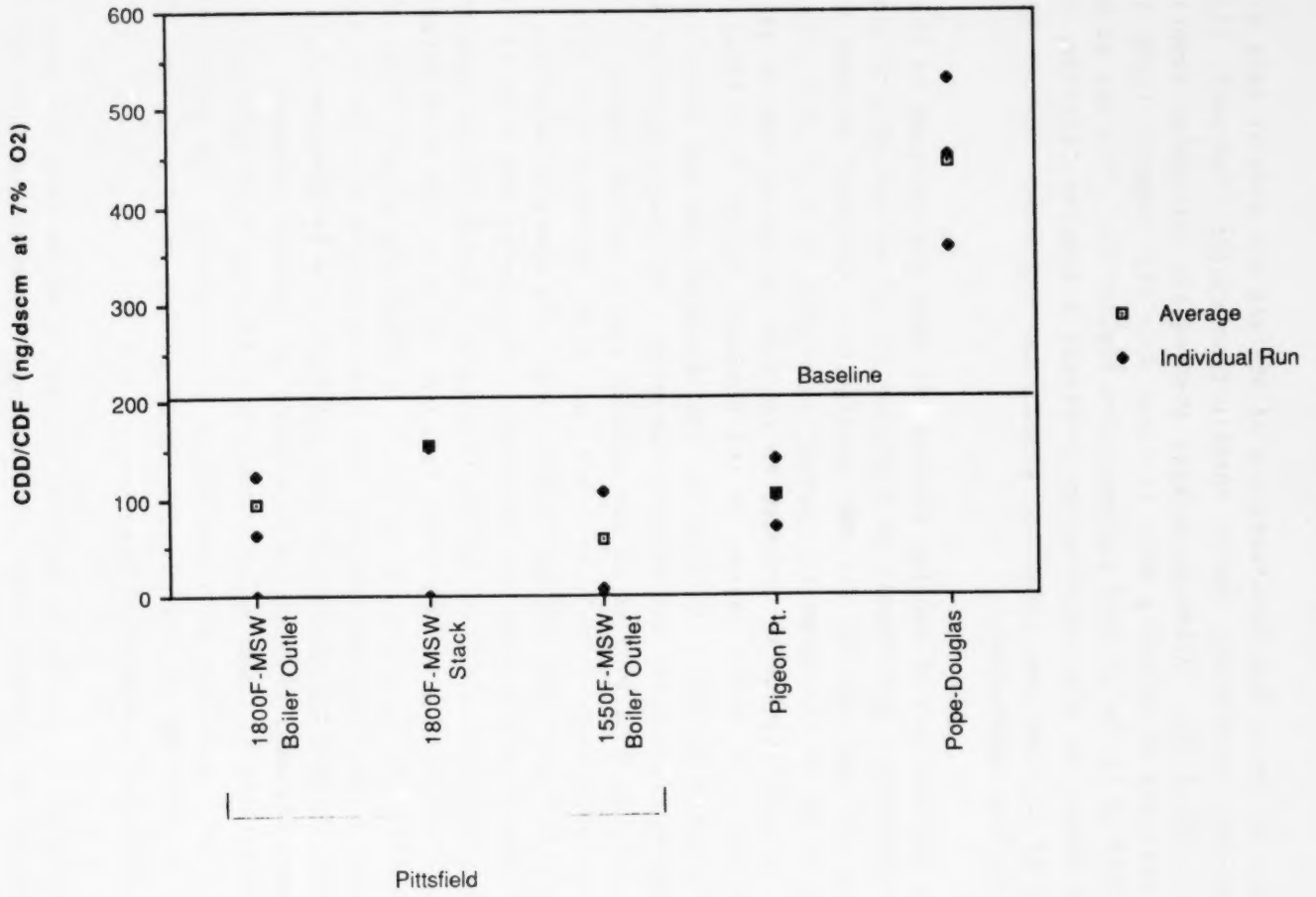

Figure 3-5. Modular Excess Air Baseline Determination

3.5 Mass Burn Modular Starved Air MWCs

There are at least four manufacturers of starved air modular MWCs with units in planning, permitting, and/or construction stages (Consumat, Clean Air, Joy, and John Zink). Although modular starved air facilities comprise the largest category of existing MWCs in total facility numbers, there are very few identified in the planned and projected population. This may be due to the short amount of time required to construct a modular facility; the current list of planned and projected plants may represent shorter term projections for this population.

Generic descriptions of modular starved air MWCs are included in EPA's MWC Report to Congress. Refinements in combustor design and controls continue to be made in the new starved air MWC population. Consumat Systems has increased the volume of the secondary combustion chamber in their more recent designs.[26] This modification is intended to increase residence time of gases for better mixing. A second change in the Consumat design is related to control of the charging rate. Originally, the charging rate was based on a pre-established interval which was adjusted manually. The loader operator was given a signal every 5-10 minutes to add another charge to the loader. The size of the charge (heavy, normal, or light) was also indicated by a signal which was based on the primary chamber temperature. The operator adjusted the size of individual charges based on the signal, increasing the size if the temperature was below the setpoint and decreasing the charge if the setpoint temperature was exceeded. In the newer Consumat designs, the time between charges is automatically adjusted based on a feedback signal from the temperature controller. The operator does not have to adjust the size of each charge manually; instead the controller will automatically lengthen or shorten the time between charges, eliminating dependency on operator judgment. This feature may contribute to lower organic emissions, because it is hypothesized that CDD/CDF levels correlate with the number of CO spikes. The adjustable feed control sequence may provide less frequent spikes in CO emissions and lower uncontrolled trace organic emissions.

The Joy design is similar to Consumat in that transfer rams are used to move waste through the primary combustion chamber. Some unique features in the Joy system are an underfire air and steam injection system for temperature control, and a modulating temperature controller which automatically adjusts

the induced draft (ID) fan damper. The air/steam injection system in the primary chamber is designed to reduce high localized hearth temperatures to minimize clinker formation and minimize vaporization of inorganics (metals). In addition, alternating the exposure of the waste to underfire air and steam reportedly maximizes the conversion of fixed carbon content of the waste to CO_2. The automatic control of the ID fan damper results in fewer furnace upsets due to pressure imbalances, changes in draft, or changes in total combustion gas flow. When these upsets occur and temperatures increase, a thermocouple in the dumpstack senses the increase in temperature and the controller drives the ID fan damper to a more open position, resulting in improved system stability. If the thermocouple senses an immediate decrease in temperature the ID fan damper is driven to a more closed position, which reduces air flows and boosts operating temperatures.

3.5.1 Existing Facilities Emissions Data

CDD/CDF emissions data are available from several modular starved air MWCs. The most recent data has been gathered by Environment Canada at Prince Edward Island (PEI) and by New York DEC at the Oswego, Oneida, and Cattaraugus County MWCs. Uncontrolled data are available from PEI, Cattaraugus County, and Oswego. The available emissions data are included in Table 3-5 along with a comparison of individual plant performance relative to the good combustion practice recommendations for modular starved air MWCs.

3.5.1.1 Prince Edward Island

Emissions testing was performed at PEI at four operating conditions (normal, long feed cycle, high secondary chamber temperature, and low secondary chamber temperature). The facility consists of three Consumat CS-1600 combustors, each rated at 36 tpd (33 Mg/day). The combustors exhaust to a common waste heat recovery boiler and then to a stack without further emissions control. A process schematic of the facility is provided in Figure 3-6. Sampling was performed at the boiler inlet location and in the stack. The primary operating variables were primary and secondary combustion temperatures and feed cycle. Three sampling runs were performed for each condition. The average CDD/CDF and CO data are presented in Table 3-6 for each operating condition.[5]

TABLE 3-5. MODULAR STARVED AIR MWCS - PERFORMANCE ASSESSMENT
PAGE 1 OF 2

FACILITY		Prince Edward Island
NUMBER OF UNITS - FGC		3 - None
UNIT SIZE, tpd (Mg/day)		36 (33)
UNCONTROLLED EMISSIONS		
CDD/CDF (ng/dscm)		
CO (ppmv)		409
PM (mg/dscm)		62
		225
CONTROLLED EMISSIONS		
CDD/CDF (ng/dscm)		--
CO (ppmv)		--
COMBUSTION PARAMETERS CONDITIONS	GOOD COMBUSTION PRACTICE RECOMMENDATIONS	FACILITY DESIGN AND OPERATING
DESIGN		
Temperature at fully mixed height	1800°F (982°C) average	1832°F (1000°C) (secondary chamber)
Secondary air capacity (not an operating requirement)	80% total air	NA
Secondary air injector design	That required for penetration and coverage	NA
Auxiliary fuel capacity	As required to achieve temperature limits during start-up	NA
Exit gas temperature	<450°F (232°C) at PM control device inlet	363°F (184°C)
OPERATION		
Excess air	6-12% O2 (dry)	12% O2
Turndown	80-110% design load	NA
Secondary air	80% total air	NA
Start-up procedures	On auxiliary fuel to design temperature	NA
Auxiliary fuel use	High CO, low temp; start-up/shutdown	NA
VERIFICATION		
O2 levels	Monitor	No
CO	Monitor (<50 ppm at 7% O2)	No
Temperature	Monitor	Primary and secondary chamber
Air distribution	Monitor	No
Exit gas temperature	Monitor	No

TABLE 3-5. MODULAR STARVED AIR MWCS - PERFORMANCE ASSESSMENT
PAGE 2 OF 2

FACILITY	Cattaraugus County, NY	Oneida County, NY
NUMBER OF UNITS - FGC	3 - None	4 - ESP
UNIT SIZE, tpd (Mg/day)	38 (35)	50 (45)
UNCONTROLLED EMISSIONS		
CDD/CDF (ng/dscm)	345	--
CO (ppmv)	NA	--
PM (mg/dscm)		
CONTROLLED EMISSIONS		
CDD/CDF (ng/dscm)	--	462
CO (ppmv)	--	--
COMBUSTION PARAMETERS	FACILITY DESIGN AND OPERATING CONDITIONS	FACILITY DESIGN AND OPERATING CONDITIONS
DESIGN		
Temperature at fully mixed height	1800-2000°F (983-1093°C) (secondary exit)	1800°F (983°C) (secondary exit)
Secondary air capacity (not an operating requirement)	At least 40% total air	NA
Secondary air injector design	NA	NA
Auxiliary fuel capacity	Gas - 30% load	Gas - 100% (not used)
Exit gas temperature	502°F (216°C) (stack)	400-450°F (204-232°C) (boiler outlet)
OPERATION		
Excess air	NA	NA
Turndown	NA	NA
Secondary air	40% of total air	NA
Start-up procedures	On gas to 1800°F (983°C) in secondary	Not used
Auxiliary fuel use	Start-up	None
VERIFICATION		
O2 levels	No	No
CO	No	No
Temperature	Primary and secondary chamber	Primary and secondary chamber
Air distribution	Primary air	No
Exit gas temperature	Yes	Yes

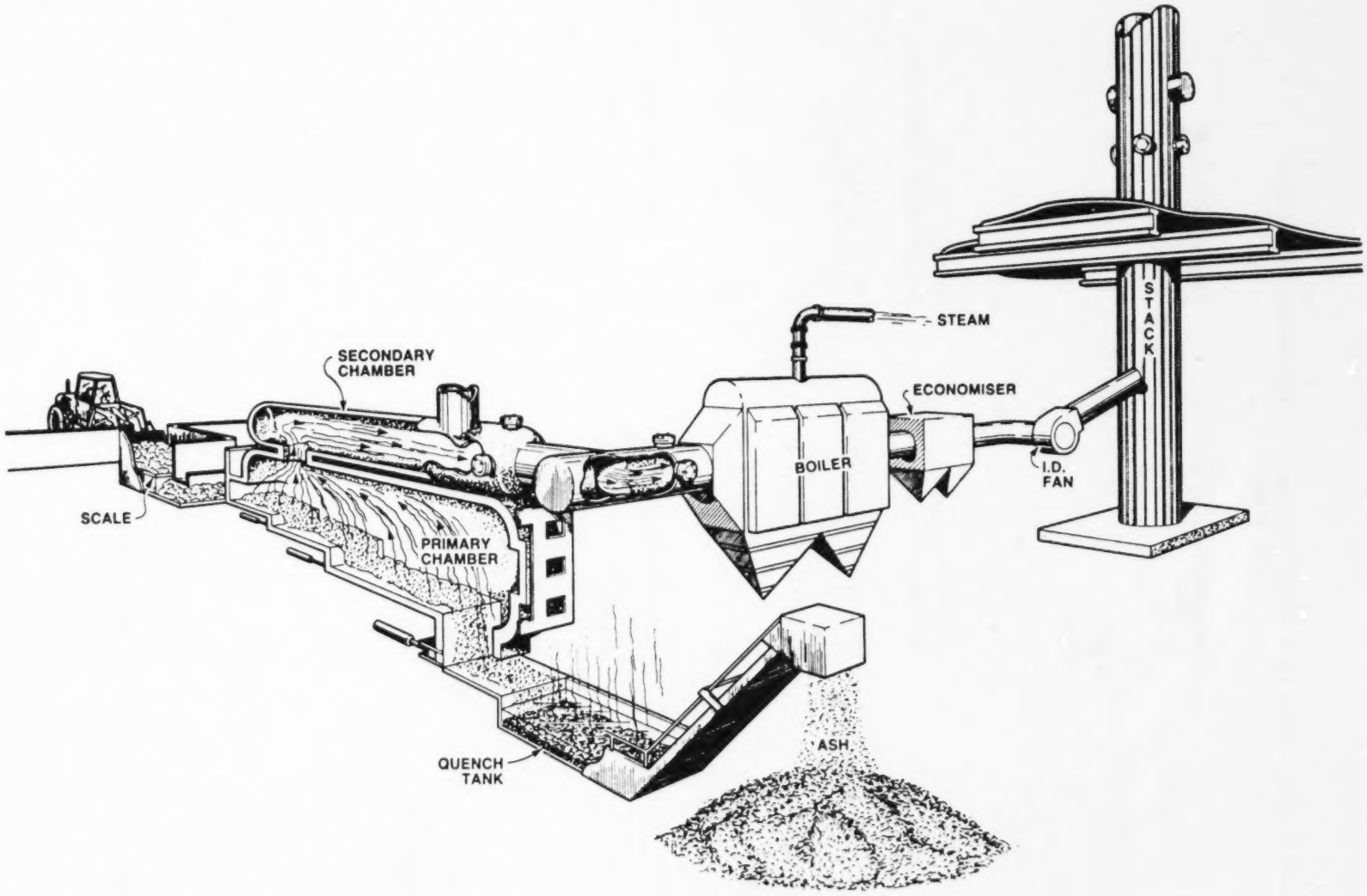

Figure 3-6. Prince Edward Island MWC

TABLE 3-6. PERFORMANCE TEST DATA
PRINCE EDWARD ISLAND MWC

	BOILER INLET			STACK			
CONDITION	CDD/CDF (ng/dscm)	TEMPERATURE °F	°C	CDD/CDF (ng/dscm)	CO (ppmv)	TEMPERATURE °F	°C
Normal	NA	1544	840	409	62	363	184
Long Cycle	0	1544	840	441	39	363	184
High Secondary	1	1922	1050	198	38	361	183
Low Secondary	42	1364	740	424	53	266	130

The data in Table 3-6 indicate that CDD/CDF emission levels in the stack are partially due to formation that occurs in the lower temperature portions of the system. With the exception of the low secondary temperature conditions, CDD/CDF emissions are near zero at the boiler inlet. The higher emission levels during the low secondary temperature condition likely result from insufficient temperatures to provide destruction of CDD/CDF and precursors. Secondly, the operating variable that had the most noticeable effect on CDD/CDF stack emissions was the high secondary chamber temperature. These data provide support for the combustion temperature requirements in the MWC recommendations.

3.5.1.2 Cattaraugus County, New York

The second set of CDD/CDF emissions data was gathered at the Clear Air facility in Cuba (Cattaraugus County), NY. The plant consists of three 38 tpd (35 Mg/day) units that began operating in 1983. The plant has heat recovery but uses no flue gas cleaning device. Two CDD/CDF sampling runs are available from testing performed by New York State in 1984, and average emissions were reported to be 345 ng/dscm.[27] There are no CO data available with the test results. Primary chamber temperatures were approximately 2200-2300°F (1204-1260°C) and secondary chamber temperatures were maintained near 2000°F (1093°C) during testing.

3.5.1.3 Oneida County, New York

Oneida County is another Clear Air facility which comprises four units at 50 tpd (45 Mg/day) each. The plant has heat recovery in place and is equipped with an ESP. Stack testing was performed by New York State DEC in 1985. Average CDD/CDF emissions at Unit #1 were 462 ng/dscm.[15] The temperature at the ESP inlet was 458°F (237°C). Primary chamber temperatures were approximately 1600-1800°F (871-982°C) and secondary chamber temperatures were 1700-2000°F (927-1093°C) during testing.

3.5.1.4 Additional Data

Uncontrolled PM emissions data are available from Tuscaloosa, AL [0.07 gr/dscf (160 mg/dscm)][14], PEI [0.098 gr/dscf (225 mg/dscm)][5], and Windham, CT [0.07 gr/dscf (160 mg/dscm)].[28] CO emissions are available from PEI (38-62 ppmv)[5] and from Red Wing, MN (2 ppmv).[14]

The available emissions data provide evidence that relatively low CDD/CDF concentrations can be achieved by modular starved air MWCs. The key conditions that lead to low emissions are the same as specified for other technologies: achieve good mixing at adequate temperature and minimize the conditions that lead to downstream formation of CDD/CDF. Starved air MWCs can achieve adequate secondary chamber temperatures by control of air flows. The fully mixed location in a modular starved air MWC can be defined at the exit of the secondary combustion chamber. The available data also indicate that total elimination of downstream formation of CDD/CDF may not be feasible. However, systems should be designed and operated in a manner which minimizes the potential for these occurrences.

3.5.2 Model Plant Baseline Emissions

Figure 3-7 presents the available CDD/CDF emissions data in graphical form. Based on the available emissions data and on judgements that design improvements made to new systems (as discussed above) will result in lower emission levels, baseline uncontrolled CDD/CDF emissions were established at 300 ng/dscm. Based on available data from several existing facilities, newer facilities are also expected to be able to achieve uncontrolled particulate matter emissions of 0.1 gr/dscf (230 mg/dscm) and CO emissions of 50 ppmv.

3.6 Model Plant Performance Estimates - RDF Combustors

Refuse-derived-fuel (RDF) combustion technology includes the use of conventional RDF spreader stokers, fluidized bed combustors (FBC), and RDF co-firing in coal fired boilers. The RDF model plants in this analysis include two spreader stokers and two FBC facilities. One of the spreader stoker model plants burns 100 percent RDF and one burns a 50/50 mixture of RDF and wood waste. Based on projections of the new population of FBCs, one circulating fluidized bed (CFB) model plant and one bubbling fluidized bed model plant were developed. Both of the fluidized bed models are assumed to burn 100 percent RDF.

3.6.1 RDF Spreader Stokers

The population of planned and projected RDF fired spreader stoker boilers is anticipated to include two major manufacturers--Babcock & Wilcox

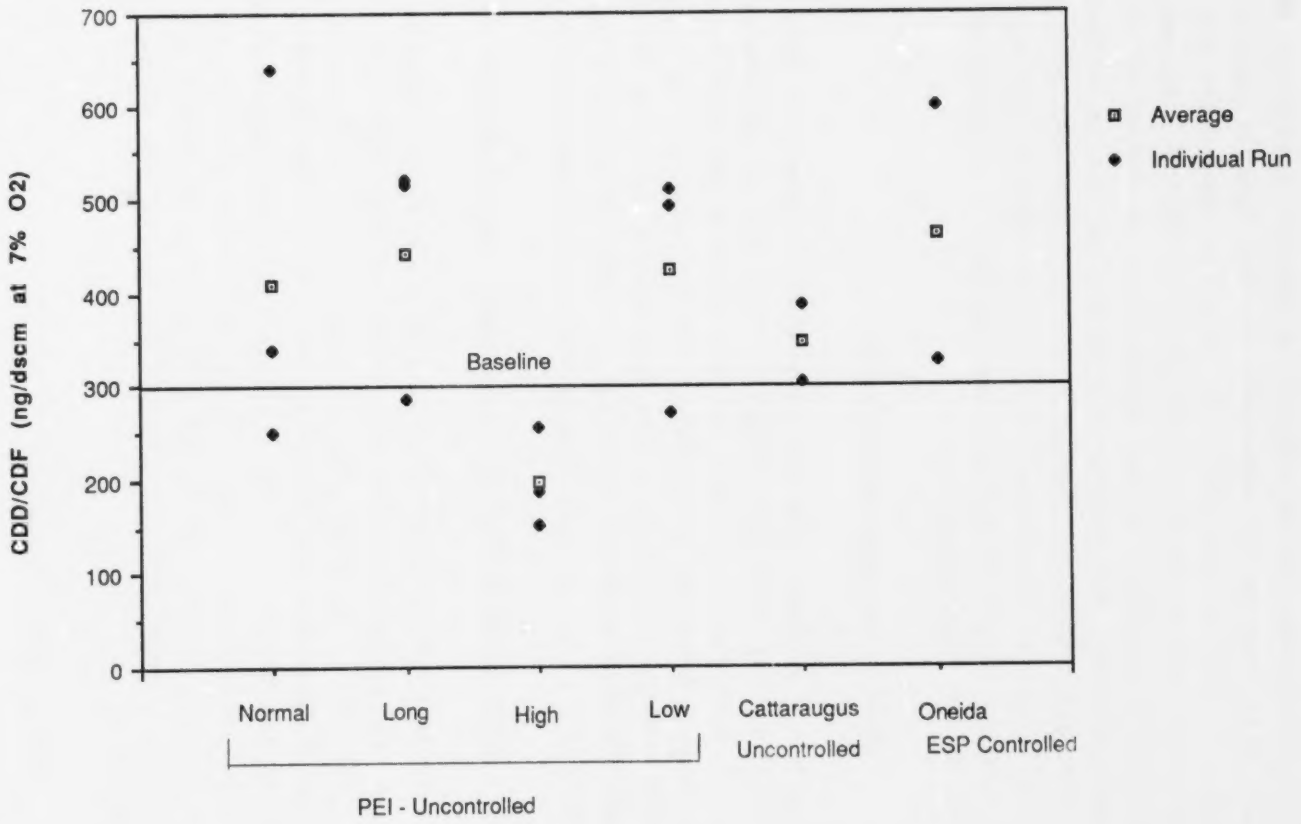

Figure 3-7. Modular Starved Air Baseline Determination

(B&W) and Combustion Engineering (CE). Both of these manufacturers have developed new RDF combustors with unique design features.

Figure 3-8 shows the configuration of the new B&W design. The lower portion of the boiler is pinched to provide arches in the front and rear wall and a row of overfire air nozzles is located at each arch. Overfire air is also injected below the arches. The configuration is designed to provide a well mixed region in the lower furnace above the traveling grate. The first facility to use this design is the Maine Energy Recovery Company (MERC) plant at Biddeford, ME. Another design feature which is characteristic of new RDF fired MWCs is a metered feeding system. A Detroit Stoker metered feeding system (shown in Figure 3-9) is also used at MERC. The metered feeding system consists of two RDF hoppers, a ram feeder, and a variable speed conveyor which transports RDF to air swept distributors at a constant rate, thus providing a consistent fuel feed rate and uniform distribution of waste on the traveling grate.

A second new RDF boiler design being supplied by Combustion Engineering includes multiple, separately controllable underfire air plenums (Figure 3-10). This design provides the operator with the ability to vary underfire air distribution to each region of the waste bed based on the distribution of fuel on the grate. A second unique design feature in the CE boilers is the overfire air system. There are tangential overfire air jets located in the furnace corners, each of which includes three levels of separately controllable nozzle banks. There are also three rows of overfire air nozzles on the furnace walls (one row on the front wall and two rows on the rear wall). Although the wall fired air is normally operated when burning coal, the tangential and wall overfire air systems can be fired simultaneously.

Metered feeding and segmented underfire air supplies are both designed to accomplish the same objective: to provide uniform stoichiometries in the grate/fuel bed region of the furnace. This is a necessary requirement for achieving good combustion. The objective can be accomplished either by biasing the supply of combustion air to the portion of the grate where the waste is concentrated, or by distributing the waste evenly on the grate with underfire air delivered from a single plenum.

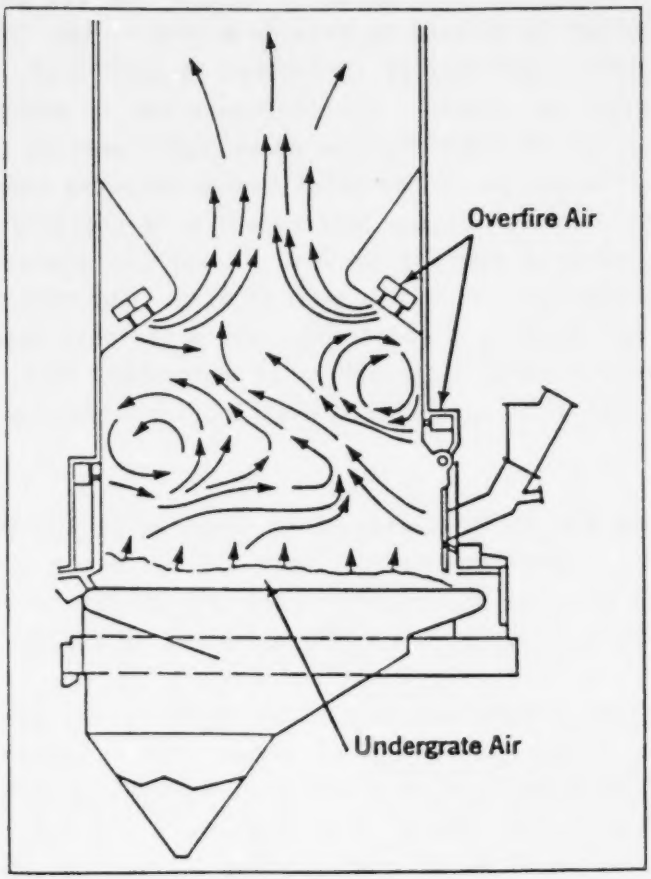

Figure 3-8. MERC - B&W Boiler Design

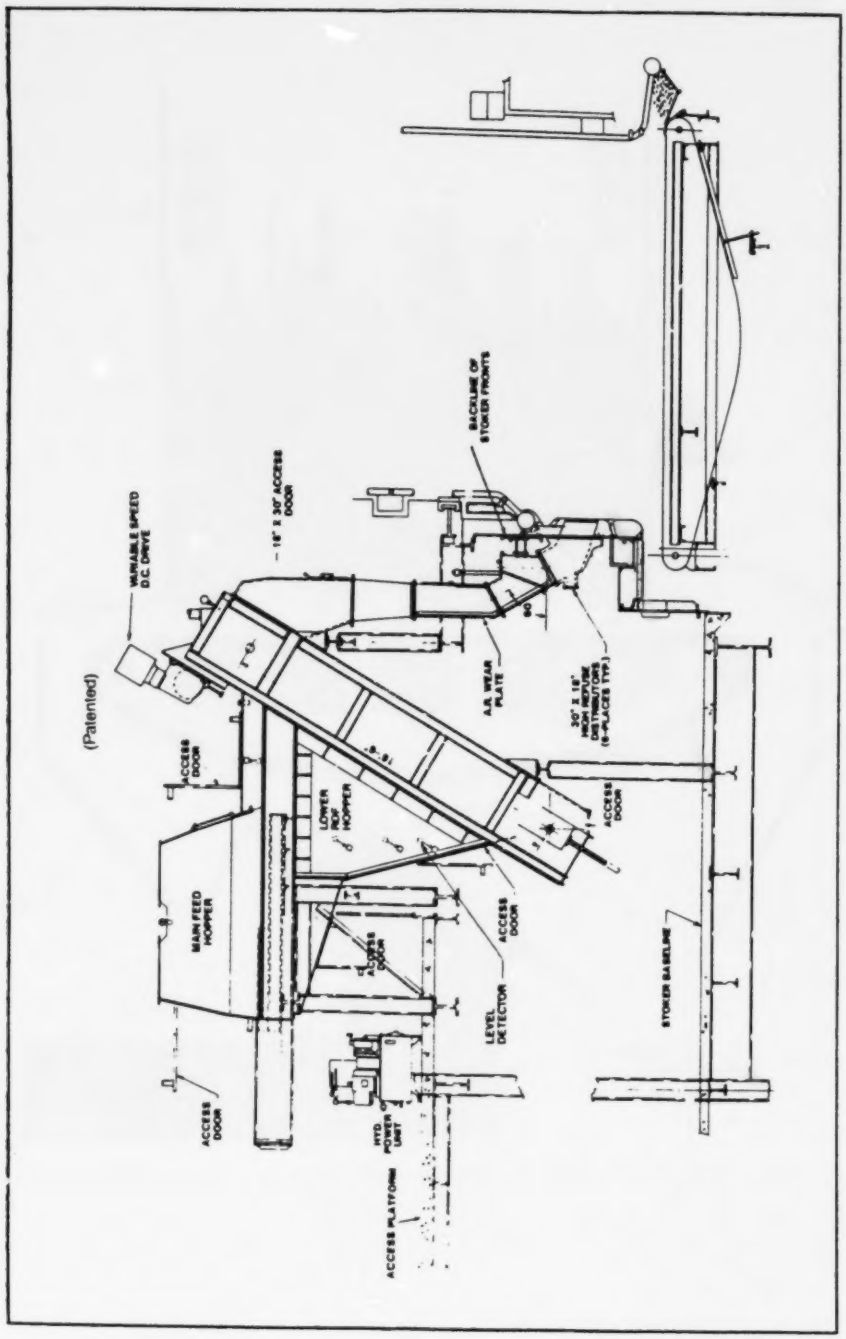

Figure 3-9. Detroit Stoker RDF Metered Feed System.

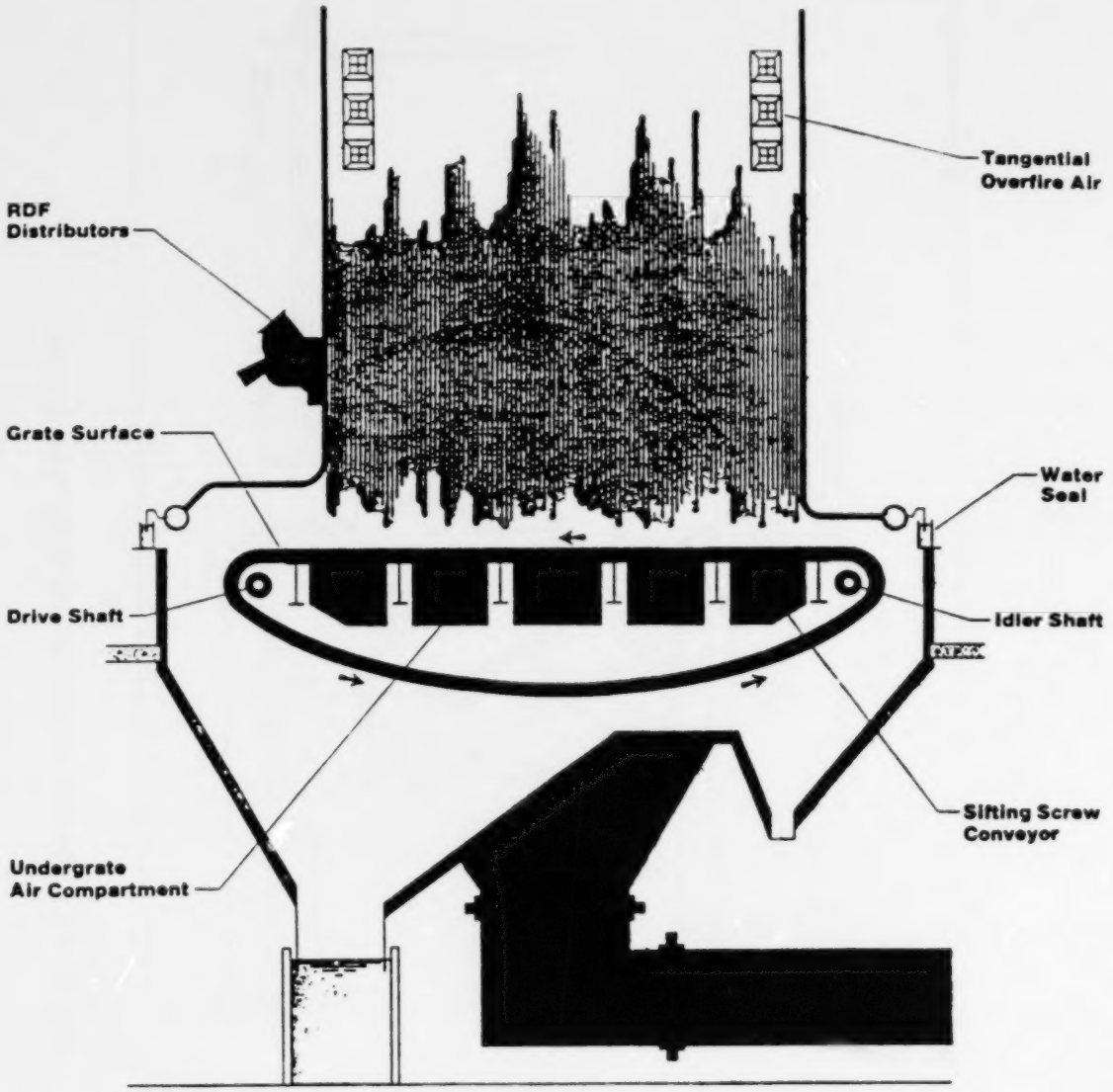

Figure 3-10. Mid-Connecticut CE RDF Fired MWC

3.6.2 Existing Facilities Emissions Data

A summary of emissions test data is presented in Table 3-7 for RDF fired facilities that are judged to be representative of the planned and projected population.

3.6.2.1 Biddeford, Maine

The Biddeford, ME, MWC was tested for CDD/CDF by EPA in December 1987. The plant comprises two boilers, each rated at 350 tpd (318 Mg/day) RDF. Emissions control on each unit is achieved by a cyclone, a spray dryer, and a baghouse. Emissions were measured at the spray dryer inlet (downstream of the cyclone) in conjunction with compliance testing performed in the stack. The unit that was tested was operating at full load during the test. Although an RDF/wood mixture is fired during normal operating conditions, 100 percent RDF was burned during the test. Three CDD/CDF sampling runs were performed and average unabated emissions were 903 ng/dscm.[29] Inlet particulate emissions were 3.56 gr/dscf (8190 mg/dscm), and average CO emissions were 81 ppmv. The boiler was operated at approximately 65-70 percent excess air during the test with an overfire/underfire ratio of 56/44. Each test run was 4 hours' duration. The average temperature at the spray dryer inlet location was 374°F (190°C).

3.6.2.2 Red Wing, Minnesota

The Red Wing facility comprises two 35-year-old coal-fired spreader stoker boilers that have been retrofitted to burn 100 percent RDF.[30] The boilers were enlarged by extending the furnace down into the basement, removing the coal bottom ash hoppers, lowering the stokers, and adding a 14-foot (4.3 m) waterwall extension fabricated from membrane panels with high nickel alloy weld overlay. The existing tube and tile upper furnace was connected to the new membrane walls by installation of a transition header. A new multilevel, multipoint, heated overfire air system was installed to ensure good mixing.

The facility was tested for CDD/CDF in 1987. Emissions at the ESP inlet were reported to be 60 ng/dscm and average stack emissions were 28 ng/dscm.[31] Inlet particulate emissions were reported to be 2.13 gr/dscf (4900 mg/dscm)

TABLE 3-7. RDF FIRED SPREADER STOKERS - PERFORMANCE ASSESSMENT
PAGE 1 of 2

FACILITY		Red Wing, MN
NUMBER OF UNITS - FGC		2 - ESP
UNIT SIZE, tpd (Mg/day)		360 (318)
UNCONTROLLED EMISSIONS		
CDD/CDF (ng/dscm)		NA
CO (ppmv)		127
PM (mg/dscm)		4900
CONTROLLED EMISSIONS		
CDD/CDF (ng/dscm)		28
CO (ppmv)		99
COMBUSTION PARAMETERS	GOOD COMBUSTION PRACTICE RECOMMENDATIONS	FACILITY DESIGN AND OPERATING CONDITIONS
DESIGN		
Temperature at fully mixed height	1800°F (982°C) mean	>1800°F (982°C) inlet to first convective section
Underfire air control	As required for uniform bed stoichiometry	2 plenums
Overfire air capacity	40% total air	50% total air
Overfire air injector design	Penetration and coverage	
Auxiliary fuel capacity	As required to achieve temperature limits during start-up	100% load
Exit gas temperature	<450°F (232°C) at PM control device inlet	260-450°F (127-232°C)
OPERATION		
Excess air	3-9% O2 (dry)	7-11% O2
Turndown	80-110% of design	40% minimum
Overfire air	Coverage and penetration	50% at full load 20% at minimum load
Start-up procedures	Auxiliary fuel	Gas
Auxiliary fuel use	High CO, low temp; start-up/shutdown	Start-up
VERIFICATION		
O2 levels	Monitor	Yes
CO	Monitor (100 ppm at 7% O2)	Yes
Temperature	Monitor	Yes
Air distribution	Monitor	Yes
Exit gas temperature	Monitor	Yes

TABLE 3-7. RDF FIRED SPREADER STOKERS - PERFORMANCE ASSESSMENT
PAGE 2 of 2

FACILITY	Biddeford, ME
NUMBER OF UNITS - FGC	2 -
UNIT SIZE, tpd (Mg/day)	300 (272)
UNCONTROLLED EMISSIONS	
CDD/CDF (ng/dscm)	903
CO (ppmv)	81
PM (mg/dscm)	8190
CONTROLLED EMISSIONS	
CDD/CDF (ng/dscm)	--
CO (ppmv)	--
COMBUSTION PARAMETERS	**FACILITY DESIGN AND OPERATING CONDITIONS**
DESIGN	
Temperature at fully mixed height	Not Available (NA)
Underfire air control	Metered fuel feeding
Overfire air capacity	60% total air
Overfire air injector design	
Auxiliary fuel capacity	Gas - 40% load
Exit gas temperature	374°F (190°C) at PM control device inlet
OPERATION	
Excess air	7% 02
Turndown	40% minimum (on gas)
Overfire air	60% total air
Start-up procedures	Gas to 1800°F (982°C)
Auxiliary fuel use	Routinely co-fire, start-up, shutdown
VERIFICATION	
02 levels	Yes
CO	No
Temperature	Not currently measured
Air distribution	NA
Exit gas temperature	Yes

and average CO levels were 127 ppmv (5-hour average). The Red Wing units are designed to operate at 65 percent excess air with a 50/50 overfire/underfire air ratio. The average excess air level was 62 percent during CDD/CDF testing, and the air distribution was not specified. The design ESP inlet temperature is 420°F (216°C) and the average operating value was 425°F (218°C).

After the data were subjected to an EPA QA/QC review, the inlet CDD/CDF data were invalidated. Therefore, only the data measured in the stack were included in this analysis.

3.6.3 Model Plant Baseline Emissions

Based on the measured data from Biddeford, the baseline CDD/CDF emission levels for new RDF units have been established at 1000 ng/dscm. Baseline CO values of 100 ppmv are established for the model plants. This CO emissions level is expected to be achievable by new RDF fired units in a short term (4-hour) test. Average uncontrolled PM emissions of 4 gr/dscf (9200 mg/dscm) were assumed for the model plants based on the Biddeford data.

3.7 RDF/Wood Co-Fired MWCs

At this time there are no data available to establish baseline CDD/CDF emissions for RDF boilers that fire mixtures of RDF and wood. Although untreated wood will probably have lower chlorine contents than RDF, the ring structure organics emitted from the combustion of wood could possibly contribute to CDD/CDF formation. Due to the absence of data to indicate otherwise, the same baseline emission levels are assumed for spreader stokers firing mixtures of wood and RDF: 1000 ng/dscm CDD/CDF, 100 ppmv CO, and 4 gr/dscf (9200 mg/dscm) PM.

3.8 Fluidized Bed Combustors

There are two FBC model plants; one bubbling bed facility and one circulating fluidized bed (CFB) plant. The actual growth rate of CFB combustion units in the U.S. is questionable at this time. Several communities reportedly have plans for new CFB units, but very few are in construction or permitting stages.[32]

3.8.1 Existing Facilities Emissions Data

The two fluidized bed MWCs in the U.S. (Duluth, MN and Lacrosse, WI) are both bubbling bed designs. Each plant has been tested for CDD/CDF. Discussion of test results is provided below.

3.8.1.1 Duluth, Minnesota

The Duluth facility normally combusts a mixture of RDF and sewage sludge [120 tpd (109 Mg/day) fluff RDF and 345 tpd (314 Mg/day) sludge at 18 percent solids]. Emissions are controlled by a venturi scrubber. Testing was performed at full operating load. Total tetra-octa CDD/CDF were measured in the stack downstream of the control device. The average emission levels of CDD/CDF over three runs were approximately 7.7 ng/dscm at 7 percent O_2.[33] Sixty-two 15-minute averages of the CO emissions from the Duluth FBC indicated levels between 1 and 31 ppm. Controlled particulate emissions levels were 0.0048 gr/dscf (11 mg/dscm).

3.8.1.2 LaCrosse, Wisconsin

Diagnostic and compliance tests were conducted at the Northern States Power French Island Facility Unit #1 at Lacrosse, WI in May 1988. All testing was conducted at the stack, downstream of the electrified granular bed filter. The unit combusts a mixture of fluff RDF [185 tpd (168 Mg/day)] and wood chips [175 tpd (159 Mg/day)]. The average CDD/CDF emissions level observed in three runs was 14.3 ng/dscm.[34] CO emissions at NSP averaged 275 ppm over three runs. The total particulate concentration at the stack averaged 0.0184 gr/dscf (42 mg/dscm) over three runs. The gravel bed scrubber reportedly operates at 325°F (163°C).

3.8.1.3 Sundsvall, Sweden

Stack emissions test data are reported by Gotaverken for a CFB facility in Sundsvall, Sweden co-firing peat, wood, and tires with RDF.[35] Weight percentages of each of the fuels are not specified in the test reports. The average reported CDD/CDF concentration was 392 ng/Nm^3. Carbon monoxide emission data from Sundsvall indicate that the units can maintain concentrations below 100 ppmv.

3.8.2 Model Plant Baseline Emissions

The data from the Duluth and the LaCrosse FBCs are used to establish baseline CDD/CDF emissions for the bubbling bed model plant (20 ng/dscm). The emissions data from Sundsvall are used to estimate baseline emission for the CFB models (400 ng/dscm). Both models were assumed to have CO emissions of 50 ppm. Uncontrolled PM emissions are assumed to be equivalent to PM emissions from RDF spreader stokers [4 gr/dscf (9200 mg/dscm)].

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